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HUMUS AND HUMUS-NITROGEN IN CALIFORNIA SOIL COLUMNS

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INTRODUCTION

Humus, as distinct from the unhumified organic matter, is now regarded as one of the most valuable ingredients of fertile soils because of its physical effect and because of its content of nitrogen, potash, and phosphoric acid, which while not soluble in water, are rendered available to plant use by the action of soil bacteria. It has no definite chemical composition, for it is produced by the decay of vegetable and animal matters of all kinds in the soil and under certain conditions of warmth and moisture, and is naturally made up of the elements found in those substances; during the process of humification, however, there is a gain in the percentage of carbon and nitrogen because of corresponding losses of oxygen and hydrogen. The proportion of these and of mineral matters in the humus varies then with the nature of the substances from which they are derived, and probably with the degree of intensity of the action of each factor in the humification process, in which oxidation because of too great heat, or other changes because of excess of water may be brought about.

The amount of humus produced from organic matter depends upon the nature and condition of the materials used, and upon its complete humification by the maintenance of proper conditions in the soil. Professor Hilgard[1] thinks that "in the humid region one part of normal soil humus might be formed from five or six parts of dry plant debris; while in the extreme regime of the arid regions from eighteen to twenty parts of the same

[1] Soils (Macmillan & Co., 1906), p. 128.

would be required." The experiments of Professor Harry Snyder of Minnesota[2] on the humification of different materials gave interesting results. Humification under favorable conditions was allowed to proceed a year in each case, at the end of which time the amount of humus obtained from each substance and its composition was ascertained. Oat straw and sawdust seemed unchanged even when humification was allowed to continue longer than a year. The following table illustrates some of Snyder's findings:

TABLE 1.—HUMUS OBTAINED FROM DIFFERENT MATERIALS

Fresh cow manure	33 parts for 1 part of humus	6.16% nitrogen in humus
Green clover	25 parts for 1 part of humus	8.24% nitrogen in humus
Meat scraps	11 parts for 1 part of humus	10.96% nitrogen in humus
Sawdust	10 parts for 1 part of humus	0.30% nitrogen in humus
Oat straw	6 parts for 1 part of humus	2.50% nitrogen in humus

With ordinary green-manure crops and under field conditions it will probably require a much larger amount of green material to produce one part of humus, for there are losses from the incomplete turning-under of the material and the drying-out of the soil.

It would naturally be supposed that as humus is formed by the decay of roots, leaves, etc., it would be found only where formed, whereas on the contrary, we find it quite evenly diffused through the surface soil; this even distribution is not easily accounted for without some outside agencies. Professor Hilgard, in discussing the subject,[3] attributes it chiefly to the action of fungi, insects, and earthworms.

> The vegetative fibrils (mycelia) of several kinds of molds are constantly present in the soil, and while consuming dead tissue of the higher plants, spread their own substance throughout the soil mass. . . . All these being dependent upon the presence of air for their life functions, remain within such distance from the surface as will afford adequate aeration; the depth reached depending upon the perviousness of the soil and subsoil. In the humid region this will usually be within a foot of the surface, but in the arid may reach to several feet. . . . The earthworm nourishes itself by swallowing, successively, portions of the surrounding earth, digesting a part of its organic matter, and ejecting the undigested earth in the form of "casts" such as may be seen by thousands on the surface of the

[2] Bulletin 53 Minn. Agr. Exp. Station.

[3] Soils (Macmillan & Co., 1906), p. 157.

ground during and after a rain. . . . In humid climates and in a ground fairly stocked with these worms the soil thus brought up may amount to from one-tenth to two-tenths of an inch annually over the entire surface; so that in half a century the entire surface foot might have been thus worked over. Aside from the mechanical effect thus achieved in loosening the soil, and the access of air and water permitted by their burrows, the chemical effects resulting from their digestive processes, and the final return of their own substance to the soil mass; also their habit of drawing after themselves into their burrows, leafstalks, blades of grass, and other vegetable remains, renders their work of no mean importance both from the physical and chemical point of view. . . . The work of earthworms is especially effective in loamy soils and in the humid regions. In the arid region and in sandy soils generally the life conditions are unfavorable to the worm, and the perviousness elsewhere brought about by its labors already exists naturally in most cases.

The amount and nature of humus depends much upon climatic factors as is especially noted in arid and humid regions. In the humid region with its frequent rainfall and a comparatively shallow soil, the vegetable material (roots, leaves, etc.) is held near the surface and to this depth the humus is limited; while in the very deep and warm soils of the arid region the penetration of plant roots is to depths of fifteen to thirty feet, and as a consequence of their decay humus is found to depths of twelve or fifteen feet and in some cases much deeper.

It is this deep distribution of humus throughout the agricultural regions of California that is treated of in detail in this bulletin, showing a fundamental difference between the soils of humid and arid regions.

HUMUS IN CALIFORNIA SOILS

The study of the soils of California was begun by Professor Hilgard immediately after entering upon his duties in 1874 as Professor of Agriculture in the University of California, and his first report, made in 1877, contains physical and chemical analyses together with descriptions of a number of soils, as well as the results of alkali investigations. The analysis of a soil for its humus content is first given in the report of the Experiment Station for 1879, and since then nearly every annual report to and inclusive of 1904 contains soil descriptions and analyses, the percentage of humus being given for the first foot or sometimes

for the upper two feet, as it was not then known that the humus reached to a greater depth than three feet. In the report for 1904 the first analysis is given of a soil with humus to a depth of twelve feet.

During these years the call from farmers for information regarding the needs of their soils was very great, and thousands of soils were sent in for examination. These did not require an accurate and full analysis in every case, and were subjected to cursory tests[4] by which approximate determinations could be reached very quickly for phosphoric acid, lime, and humus. The results were graded into "poor" for less than 0.7 per cent; "fair" for 0.7 to 1.0 per cent; and "good" when the percentage was above 1.0, and only the surface soils were examined. From 1893 to 1908 there were made humus tests on nearly fifteen hundred soils distributed among the following agricultural regions; in this table are given the percentages of soils whose humus belonged to the several grades.

TABLE 2.—HUMUS IN SOILS OF THE AGRICULTURAL REGIONS; QUICK METHOD

Regions	No. of soils examined for humus	Percentage of soils having Good humus	Fair humus	Poor humus
Sacramento Valley	211	55	18	27
San Joaquin Valley	434	24	24	52
Foothills of Sierra Nevada	66	59	12	29
Coast Range valleys	398	64	19	17
Southern California	347	43	23	34
Average	1,456	46	21	33

It will be seen from the above that more than one-half of the soils of the Sacramento, Foothill, and Coast Range regions that were sent for examination by farmers of those regions had as much as 1 per cent of humus, though for the state at large only 46 per cent of the 1456 soils had that amount.

[4] The method of this cursory examination for humus is as follows: Take two grams of air-dried, well-mixed soil of twelve inches depth, place in a test-tube of one-half inch diameter and add about ten cubic centimeters of 10 per cent solution of potassic hydrate. Boil for a few minutes and allow the soil to settle. The potash dissolves the humus and produces a dark color of greater or less intensity according to the amount of humus present. By taking soils in which the humus percentages have already been ascertained correctly, and treating them by this short method, a scale of color intensities may be adopted by which approximate percentage of humus may be reached in most of the soils.

The results of these soil examinations have brought out the fact that, while the supply of *potash* is as a rule very large and should not need replenishment by fertilizers for decades of years and that *phosphoric acid* is generally fair in amount, except in lands that have been in wheat culture for many years, the per. centage of *humus* in all surface soils except tule swamps is quite low and has required a system of green manuring to bring the land back into tbe best condition.

Regular Analyses.—Since the establishment of the station, nearly six hundred complete analyses have been made of soils chosen to represent the different agricultural regions and conditions in the state, and among the determinations was that of the exact amount of humus in 331 surface soils. The method of analysis used was what is known as the Grandeau Method as modified by Professor Hilgard. The results, therefore, more nearly represent actual average conditions in the soils of the state. The following table shows the average percentages of humus in the soils of the several regions:

TABLE 3.—PERCENTAGES OF HUMUS IN SURFACE SOILS; REGULAR METHOD

Regions	No. of soils examined for humus	Average percentage of humus	Percentage of soils having more than 1% of humus
Tules and meadows	14	3.62	all
Coast Range valleys	91	1.69	67
Sierra Foothills	46	1.23	41
Sacramento Valley	29	1.14	50
Southern California	61	.94	28
San Joaquin Valley	67	.79	29
Desert plains and lava bed valleys	23	.51	0
General average for state	331	1.25	40

The general average of humus in the 331 surface soils taken from different parts of California and supposed to represent fairly all of the agricultural regions is 1.25 per cent. If, however, the tule marshes and the meadow lands are omitted from the calculation, then we find that the general humus percentage is 1.15.

DISTRIBUTION OF HUMUS DOWNWARD IN CALIFORNIA SOILS

A very marked characteristic of the soils of California is their *great depth,* as exemplified in the uniformity of color through a depth of several feet, their *good texture,* affording easy penetration of plant roots often to depths of twenty and even sixty feet below the surface, *abundant food* available for plant use throughout these depths, an *absence of any well-defined subsoil* except at a depth of several feet below the surface, the *absence of any compact clay substratum* differing from the surface foot, and the *presence of humus* to a depth of as much as ten or more feet. In each of these particulars the soils of California differ from those of the humid states east of the Rocky Mountains, and because of this the methods of culture are different, and in the applications of phosphate fertilizers to the soil it is only with great difficulty that they can be made to reach the feeding roots of plants.

There are several striking facts regarding the humus itself in the soils of California which deserve mention and which distinguish them from the soils of the humid region of the eastern states, one of which has but recently been brought out in the examinations that are being made of the one hundred and more typical twelve-foot columns from the chief agricultural divisions of the state. These facts are: *first,* the small percentage of humus in the first foot of all California soils as compared with the much higher percentages found in eastern soils; *second,* the distribution of the humus downward to depths of twelve and more feet in upland soils, the total amount being usually greater than that of the eastern soils; and *third,* the rather higher percentage of humus-nitrogen in the upper three feet, and the distribution of the humus-nitrogen throughout the twelve feet, thus giving the soil in the arid region a higher total of humus-nitrogen than is found in the humid soils.

Bacterial Activity in the Soil.—Another highly important advantage possessed by California in her soils is the fact recently brought out by Professor C. B. Lipman of this station in his paper, "The Distribution and Activities of Bacteria in Soils of the Arid Region".[5]

[5] Univ. Calif. Publ. Agr. Sci., vol. 1, no. 1, pp. 17, 20.

. . . that soils of the arid region at all depths studied show ammonifying powers, which are, however, generally most vigorous in the first six or eight feet. In one case ammonification was noted in soil from a depth of fifteen feet, or adjoining the water-table. . . . As for nitrification my data present again features of striking interest. They go to prove that nitrate formation, like ammonification, goes on at much greater depths in soils of the arid than in soils of the humid region. . . . That nitrification is found commonly down to a depth of five or six feet in soils of the arid region. In one case soil from an eight-foot depth showed a vigorous nitrifying power.

Professor Lipman's observations greatly emphasize the importance of having the roots of the various crops utilize the food-supplies at their command at depths of many feet; for not only is there a nitrogen supply, but our investigations on the soil columns show that the amount of available phosphoric acid and of potash is large at depths of twelve and more feet.

DISTRIBUTION OF HUMUS AND HUMUS-NITROGEN IN SOIL COLUMNS FROM EACH AGRICULTURAL REGION

The agricultural regions of the state comprise the Sacramento and San Joaquin valleys, forming together the central Great Valley, the foothills lying on the western slope of the Sierra Nevada, the many Coast Range valleys and low hills among the mountain ranges along the western side of the state, the Southern California valleys and the low hills, the desert plain, which is being brought under cultivation by the development and use of irrigation water, and the northeastern lava-bed valleys.

As the object of this investigation was chiefly to ascertain the extent to which humus was found in the lower depths of the soils, the soil columns were taken only from those regions whose soils are many feet in depth. The number of columns obtained was 110 from thirty-seven counties, each column intended to represent a characteristic type of land in its particular region. There are, of course, very many small valleys and minor soil regions that have not been included in this investigation. The columns have been placed in vertical frames against the walls of the lecture room of Budd Hall at the University of California, arranged and labelled according to the respective agricultural regions. Each soil occupies an eight-ounce bottle and the

columns are nearly eight feet in height, thus forming a very conspicuous and interesting exhibit, probably the first and only one of its kind anywhere.

The percentage of humus and of humus-nitrogen has been ascertained in all of these soils as shown in the following pages of this bulletin. The chemical analysis of the first, sixth, and lowest foot of each column and the physical analysis of the first or upper foot have been nearly completed and the results, with proper discussion, will be given in future bulletins. The humus and nitrogen determinations in the bulletin were made chiefly by Messrs. M. E. Holter and F. H. Wilson, and the late F. E. Johnson, assistants in the soil laboratory.

SOIL COLUMNS OF THE SACRAMENTO VALLEY

The valley of the Sacramento River, lying between the two great mountain ranges—the Sierra Nevada on the east and the Coast Range on the west—which unite on the north, covers an area of 6200 square miles. The valley is widest on the south, where it unites with the San Joaquin Valley. Within its area are four or five general and highly distinct soil regions, or types, each of which is represented by one or more soil columns in our collection, or eighteen in all.

Alluvial Lands.—These border the Sacramento River and are timbered with sycamore, white oak, and ash. The soil is a dark loam with little or no change to the depth of twelve feet, as shown in the soil columns, and even deeper. Three columns were taken from the following localities: Near Cottonwood, Shasta County, by W. S. Guilford; Glenn Post Office, in Glenn County, east of Willows; and near Perkins, Sacramento County, by Professor George Roberts, now of the Kentucky Agricultural College. To these is added a column of the alluvial of Chico Creek taken from the Bidwell place, at Chico, Butte County.

The alluvial lands, with the exception of the sample from the hop fields at Perkins, may be regarded as rich in humus in the upper three feet, while all show fair amounts below that depth. The soil texture is good and it is to the advantage of plant roots that the humus with its nitrogen should be thus distributed, the sum in each of the four columns being from 5.60 to 8.80 per cent.

TABLE 4.—HUMUS IN COLUMNS OF ALLUVIAL LANDS OF SACRAMENTO VALLEY

	SACRAMENTO RIVER										CHICO CREEK			
	SHASTA COUNTY, COTTONWOOD				GLENN COUNTY, GLENN P. O.				SACRAMENTO COUNTY, PERKINS				BUTTE COUNTY, CHICO			
Ft.	Soil Clay 12.54	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 29.54	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 4.49	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 11.46	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1	Dark loam....	1.50	4.93	.07	Dark loam....	1.88	3.88	.07	Sandy	.66	7.21	.05	Sandy	1.84	6.03	.11
2	Dark loam....	.91	8.13	.07	Dark loam....	1.50	3.47	.05	Sandy	.76	5.39	.04	Sandy	1.46	6.62	.10
3	Dark loam....	.51	7.65	.04	Dark loam....	1.16	3.63	.04	Sandy	.76	5.74	.05	Sandy	1.16	6.90	.08
4	Dark loam....	.60	9.83	.06	Dark loam....	.88	3.18	.03	Sandy	.76	5.76	.04	Sandy	.86	8.66	.06
5	Dark loam....	.49	10.60	.05	Dark loam....	.72	4.30	.03	Sandy	.76	2.21	.02	Sandy	.58	6.27	.05
6	Dark loam....	.53	6.49	.05	Dark loam....	.60	3.67	.02	Sandy	.64	2.63	.02	Sandy	.42	10.47	.04
7	Dark loam....	.64	8.75	.06	Dark loam....	.40	4.26	.02	Sandy	.56	4.12	.02	Sandy	.40	13.00	.05
8	Dark loam....	.52	7.50	.04	Dark loam....	.23	2.43	.01	Sandy	.64	6.16	.02	Sandy	.36	10.63	.04
9	Dark loam....	.68	7.63	.03	Dark loam....	.23	2.61	.01	Sandy	.34	4.69	.02	Sandy	.36	9.47	.04
10	Dark loam....	.42	13.30	.06	Dark loam....	.33	3.33	.01					Sandy	.46	10.25	.04
11	Dark loam....	.49	5.70	.03	Dark loam....	.20	6.00	.01					Sandy	.32	11.67	.04
12	Dark loam....	.32	10.00	.03	Dark loam....	.16	2.50	.01					Sandy	.52	7.66	.04
Sum of per cents		7.31				8.29				5.60				6.60		
Average per foot		.61	6.56	.05		.69	3.35	.03		.62	4.61	.03		.73	9.20	.06
*Upper 3 feet:**																
Sum of per cents		2.92				4.54				2.20				4.46		
Average per foot		.97	6.90	.06		1.51	3.60	.05		.73	5.10	.05		.49	6.50	.10

* Range of most annual plant roots.

There is but little doubt that the humus in both the Cottonwood and Chico soils reaches much deeper than the twelve feet in which the percentage is quite large, for the soil texture is especially favorable for deep development of tree and plant roots, from the decay of which the humus was doubtless derived. In the Chico column there is a sudden increase of humus in the twelfth foot (0.52 per cent), which would indicate former strong development of roots at that point, probably just above a water stratum.

The humus of the Cottonwood column is richest in nitrogen in the upper three feet and shows remarkable and a sudden increased percentage in the tenth foot.

The Chico humus is interesting because of its richness in nitrogen in the lower half of the column.

The Cottonwood and Chico columns alone of the four have humus in sufficient amount and richness to give general averages of more than 0.05 per cent of nitrogen in the entire soil column, and are the only ones having as much as 0.10 per cent of nitrogen in the upper three feet of soil.

Clay Loams of the Valley.—These reach south from near Red Bluff and occupy the central part of the Sacramento Valley. As typical of this class of soils, seven columns were obtained from the following localities: three miles west of Tehama, Tehama County; Willows, Glenn County; J. W. Walton's place a few miles south of Yuba City, Sutter County; Woodland, Yolo County; the University Farm, Davis, Yolo County; Live Oak, Sutter County, and from near Elmira, Solano County. In each case a depth of twelve feet was reached, except at Live Oak, where at nine feet the presence of water prevented a deeper sampling.

The clay loams of the Sacramento Valley are generally deficient in humus, as shown by the first foot in each of these seven typical columns and by the results of previous examination of soils from many localities, the average being below 1 per cent. The cause is chiefly continuous grain-growing with shallow cultivation on these lands for thirty or forty years, which has depleted them. This is prominently shown in the soil from the University Farm at Davis which, before purchase by the Univer-

TABLE 5.—HUMUS IN LOAM AND CLAY-LOAM COLUMNS OF THE VALLEY PLAINS

	TEHAMA COUNTY WEST OF TEHAMA				GLENN COUNTY WILLOWS				SUTTER COUNTY NEAR LIVE OAK				SUTTER COUNTY WALTON'S, SOUTH OF YUBA CITY			
Ft.	Soil Clay 14.60	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 21.35	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 14.62	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 11.87	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1	Loam	.94	4.47	.04	Clay loam	.98	3.97	.04	Loam	.84	4.90	.04	Loam	1.27	4.65	.08
2	Loam	.78	4.31	.03	Clay loam	.54	3.50	.02	Loam	.44	6.38	.08	Loam	1.03	5.46	.08
3	Loam	.92	4.57	.04	Clay loam	.46	3.25	.02	Loam	.38	3.90	.02	Loam	.45	10.17	.05
4	Loam	.89	3.78	.03	Clay loam	.40	2.50	.01	Loam	.25	3.45	.01	Loam	.39	9.74	.04
5	Loam	.50	1.88	.01	Clay loam	.42	4.05	.02	Loam	.22	8.83	.01	Loam	.67	8.87	.05
6	Loam	.37	2.27	.01	Clay loam	.38	3.69	.01	Loam	.18	4.68	.01	Loam	.48	7.29	.04
7	Loam	.18	3.11	.01	Clay loam	.36	3.89	.01	Loam	.16	3.51	.01	Loam	.22	7.87	.02
8	Loam	.16	5.25	.01	Clay loam	.34	4.13	.01	Loam	.13	3.24	.01	Loam	.18	9.61	.02
9	Loam	.12	4.67	.01	Clay loam	.34	4.13	.01	Loam	.12	2.34	.01	Loam	.12	14.16	.02
10	Loam	.11	5.09	.01	Clay loam	.32	4.06	.01	Water				Loam	.11	13.51	.02
11	Loam	.06	.....	....	Clay loam	.28	3.91	.01					Loam	.12	10.83	.01
12	Loam	.21	.....	....	Clay loam	.28	3.91	.01					Loam	.11	7.62	.01
Sum of per cents		5.24				5.10				2.70				5.18		
Average per foot		.44	3.92	.02		.43	3.73	.02		.30	4.03	.02		.43	8.98	.03
*Upper 3 feet:**																
Sum of per cents		2.64				1.98				1.64				2.80		
Average per foot		.88	4.40	.04		.66	3.60	.03		.55	5.00	.03		.73	6.80	.06

* Range of most annual plant roots.

TABLE 5—(*Continued*)

YOLO COUNTY

UNIVERSITY FARM, DAVIS

Ft.	Soil Clay 19.12	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1	Clay loam.....	.79	4.55	.04
2	Clay loam.....	1.49	8.26	.12
3	Clay loam.....	1.15	6.34	.07
4	Clay loam.....	.85	5.83	.05
5	Clay loam.....	.58	4.31	.03
6	Clay loam.....	.54	4.68	.03
7	Clay loam.....	.39	5.60	.02
8	Clay loam.....	.31	7.09	.02
9	Clay loam.....	.66	3.33	.02
10	Clay loam.....	.60	7.50	.05
11	Clay loam.....	.87	4.82	.04
12	Clay loam.....	.69	5.65	.04
Sum of per cents		8.92		
Average per foot		.75	5.67	.04
*Upper 3 feet:**				
Sum of per cents		3.49		
Average per foot		1.16	6.40	.08

YOLO COUNTY

WOODLAND

Soil Clay 18.20	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
Clay loam.....	1.20	5.85	.07
Clay loam.....	.66	6.38	.04
Clay loam.....	.54	6.76	.04
Clay loam.....	.24	6.44	.02
Clay loam.....	.18	5.46	.01
Clay loam.....	.16	7.90	.01
Clay loam.....	.12	7.02	.01
Clay loam.....	.08	5.27	.01
Clay loam.....	.12	2.34	....
Clay loam.....	.12	3.51	....
Clay loam.....	.10	2.81	....
Clay loam.....	.14	2.01	....
	3.66		
	.30	5.14	.02
	2.40		
	.80	6.30	.05

SOLANO COUNTY

ELMIRA

Soil Clay 15.89	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
Clay loam.....	.86	4.24	.04
Clay loam.....	.62	4.98	.03
Clay loam.....	.34	3.30	.01
Clay loam.....	.28	8.51	.01
Clay loam.....	.30	2.81	.01
Clay loam.....	.30	3.28	.01
Clay loam.....	.30	3.74	.01
Clay loam.....	.26	4.32	.01
Clay loam.....	.07	.....	....
Clay loam.....	.07	.....	....
Clay loam.....	.09	.....	....
Clay loam.....	.09	.....	....
	3.58		
	.80	8.77	.02
	1.82		
	.61	6.20	.03

* Range of most annual plant roots.

sity, had been in grain culture for thirty or more years. The humus in its subsoil is nearly double that of the soil and even in the fourth foot is equal to that of the soil itself. A sample of virgin soil taken near this spot was found to have 1.25 per cent of humus, which was probably the original amount in the field, thus showing a loss of nearly 30 per cent. The nitrogen in the virgin soils was 0.07 per cent, but in the cultivated was but 0.04 per cent, which is a loss of more than 40 per cent of nitrogen.

It will be noted that the percentage of humus in the Davis soil below the upper foot is greater throughout its twelve feet than in any other of the columns. This may be accounted for by the greater development of the root systems each year and their subsequent humification. Investigation made by Mr. Farrer, formerly of the University Farm, showed that the roots of wheat, barley, and the California poppy, coincident with those of orchard trees, reached water at a depth of twelve or thirteen feet. If, as is probable, this had been the case for many years, the amount of root material for humification has been large enough for these results. The humus nitrogen of the surface foot is greatest in the Woodland and Yuba City soils, 0.07 per cent and 0.06 per cent respectively; but those columns were taken from an uncultivated lot near Woodland and from the Walton orchard south of Yuba City.

Previous analyses of other clay-loam soils gave the following percentages of humus in the surface foot: Dixon, 1.71; Kell's place near Yuba City, 1.28, and north of Willows, 3.61.

The humus in these columns from the seven localities is not especially rich in nitrogen with the exception of the lower portion of that from Walton's place south of Yuba City; but the amount of humus is so small that the nitrogen given to the soil is very little in amount. The soils from Walton's, Woodland, and Davis are the only ones of the group whose upper three feet have the normal of 0.05 per cent of humus-nitrogen, that of Davis being 0.08 per cent, or approximately 9000 pounds per acre.

Black Adobe Clay Soils.—There are several regions of these black clays within the eastern, western, and southern parts of the Sacramento Valley. One of these reaches from southwest

TABLE 6.—HUMUS IN BLACK CLAY ADOBE SOIL COLUMNS, SACRAMENTO VALLEY

	GLENN COUNTY EAST OF WILLOWS				BUTTE COUNTY NEAR BIGGS				SUTTER COUNTY SOUTHWEST OF YUBA CITY				SOLANO COUNTY SOUTH OF DIXON			
Ft.	Soil Clay 47.46	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 50.09	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 39.16	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 61.75	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1	Black clay....	1.72	5.06	.09	Black clay....	.66	5.89	.03	Black clay....	1.20	4.68	.06	Black clay....	1.05	6.66	.07
2	Black clay....	1.16	4.86	.05	Black clay....	.49	4.58	.02	Gray clay	.21	5.35	.01	Black clay....	.87	6.09	.05
3	Black clay....	.94	4.98	.05	Black clay....	.40	4.22	.02	Gray clay	.18	7.80	.01	Black clay....	.77	5.84	.05
4	Black clay....	.62	5.80	.04	Gray clay	.17	3.30	.01	Gray clay	.18	7.02	.01	Gray clay	.55	4.00	.02
5	Black clay....	.86	6.10	.02	Gray clay	.06	.....	....	Gray clay	.11	6.38	.01	Gray clay	.38	1.58	.02
6	Grayish clay	.26	9.60	.03	Gray clay	.08	.....	....	Gray clay	.10	9.82	.01	Yellow clay..	.20	4.50	.01
7	Grayish clay	.22	10.00	.02	Gray clay	.09	.....	....	Gray clay	.08	5.27	tr.	Yellow clay..	.10	1.00	.01
8	Grayish clay	.20	7.00	.01	Gray clay	.06	.....	....	Gray clay	.12	3.51	tr.	Yellow clay..	.10	.....	....
9	Grayish clay	.14	5.70	.01	Gray clay	.05	.....	....	Gray clay	.12	3.51	tr.	Yellow clay..	.10	.....	....
10	Grayish clay	.22	3.63	.01	Gray clay	.04	.....	....	Gray clay	.12	3.51	tr.	Yellow clay..	.10	.....	....
11	Grayish clay	.20	3.50	.01	Gray clay	.06	.....	....	Gray clay	.13	2.16	tr.	Yellow clay..	.09	.....	....
12	Grayish clay	.16	8.76	.01	Gray clay	.09	.....	....	Gray clay	.12	.....	....	Yellow clay..	.07	.....	....
Sum of per cents		6.20				2.25				2.67				4.38		
Average per foot		.51	5.79	.03		.19	4.49	.02		.22	5.33	.01		.36	4.24	.03
*Upper 3 feet:**																
Sum of per cents		3.80				1.55				1.59				2.69		
Average per foot		1.27	4.80	.07		.52	4.90	.02		.53	5.90	.03		.89	6.20	.06

* Range of most annual plant roots.

of Yuba City northward, passing west of Gridley and beyond Biggs. A column was taken from this belt, a few miles southwest of Yuba City, the surface soil of which contained 39 per cent of clay. Below this upper foot the color changed from black to gray. Another column was taken by Mr. F. E. Johnson from near Biggs. This contained 50 per cent of clay in its upper foot and the black color changed to gray below the third foot.

A region of black clay lies three miles east of Willows, Glenn County, whose surface foot contains 47.46 per cent of clay, and the black color extends through five feet. A column of this was taken to the depth of twelve feet.

A few miles south of Dixon, Solano County, there is a large body of very black adobe clay having 61.75 per cent of clay, and the black color passes through three feet, changing to gray below. This soil contains the highest percentage of clay thus far found in any black adobe in the state.

The black adobe clays, with the exception of that from east of Willows, are a disappointment with respect to their humus content, for we had anticipated finding fully 1.5 per cent in each of the upper three or four feet, or hoped that they would at least come up to the average of the other 109 columns of the collection, whose summation for three feet is 2.81 per cent. It is evident from the results that a black color does not always mean a high percentage of humus, for the densely black adobe of Biggs and that south of Dixon each had less than the much lighter colored soils elsewhere, and less than one-half that of the reddish alluvial soil of Chico Creek. The samples from Biggs and Yuba City are from the same belt of black adobe, though many miles apart, and each shows very small percentages below the first foot. Clearly, these clays would be greatly benefited in texture and richness by a good system of green-manuring.

The humus in the adobe soils from the several localities and even in the respective depths of each column is not uniformly rich in nitrogen, as will be seen by reference to the table. It is sometimes richest at a depth of several feet, and frequently there is a sudden and great diminution in an adjoining level, the cause of which is not apparent.

The humus of the adobe soils contains on an average about 5.5 per cent of nitrogen in the first foot and 4.9 per cent in the entire column. The amount in the top soil is greatest in the Willows adobe (0.09 per cent), and least in the Biggs soil (0.03 per cent), or an average of 0.06 for four soils. This is equivalent to 2400 pounds of organic nitrogen per acre in the surface foot which, under the proper ammonifying and nitrifying conditions, is gradually converted into an available supply for plant use.

The humus of the soil near Dixon is richest in nitrogen both in the surface foot and in the upper three feet, though the amount of humus is not so great as in that from Willows.

The amount of humus must be at least 1 per cent, and its nitrogen content must be fair to give to a soil the 0.05 per cent which is regarded as sufficient for present fertility, and we find that of these four localities the soil from Biggs falls short in the first foot and that from Yuba City in the second and third foot respectively.

The percentage in the soils is naturally less and less downward as the humus diminishes, and there are but traces of nitrogen in the lower half of each column. The natural nitrogen supply for the roots of crops must clearly come from the upper three feet in each locality, that from Willows being equivalent to about 8000 pounds per acre in three feet depth.

Red Mesa and "bedrock" Lands.—These form a wide border along the eastern and northern sides of the valley, reaching south into San Joaquin County, and are characterized by usually shallow soils underlaid by either heavy, compact red clays or by cemented beds of gravel and grit, forming a hardpan or bedrock at depths of from two to five feet below the surface. Because of the shallowness of these lands, this region is represented by but three columns; one from the bluff of Oat Creek southwest from Red Bluff, and one-half mile west of the Corning road; another from near Sheridan, Placer County, representing the lands on the eastern side of the valley; and the third from near Acampo in San Joaquin County, taken by Mr. F. E. Johnson.

The red soils from Sheridan and from the mesa southwest from Red Bluff show very low percentages of humus, not only

TABLE 7.—HUMUS IN THE SOIL COLUMNS OF RED MESA LANDS

	PLACER COUNTY SHERIDAN				TEHAMA COUNTY SOUTH OF RED BLUFF				SAN JOAQUIN COUNTY ACAMPO		
Ft.	Soil Clay 15.52	Humus	Humus-Nitrogen in Humus	Soil	Soil Clay 13.76	Humus	Humus Nitrogen in Humus	Soil	Soil	Humus	Humus Nitrogen in Humus
1	Red loam	.40	10.52	.04	Red loam	.42	6.66	.03	Red loam	.60	
2	Red loam	.38	9.21	.04	Red loam	.28	5.17	.02	Red loam	.18	
3	Red clay	.13	.....	....	Red loam	.22	2.75	.01	Red loam	.10	
4	Red clay	.10	.....	....	Red loam	.08	1.25	....	Red loam	.10	
5	Light red clay	.05	.....	....	Red loam	.09	.....	....	Red loam	.10	
6	Light red clay	tr.	.....	....	Red loam	.10	.....	....	Red loam	.07	
7	Light red clay	....	.....	....	Red loam	.07	.....	....			
8	Light red clay	....	.....	....	Red loam	.07	.....	....			
9	Light red clay	....	.....	....	Red loam	.09	.....	....			
10	Yellow clay..	....	.....	....	Red loam	.10	.....	....			
Sum of per cents		1.06				1.52				1.15	
Average per foot		.10	.....	....		.15	.....	....		.19	
*Upper 3 feet:**											
Sum of per cents		.91				.92				.88	
Average per foot		.30	9.85	.04		.31	4.80	.02		.29	

* Range of most annual plant roots.

in the first foot but in each succeeding level down to the tenth foot. The entire amount in each column is but little more than the average of the first foot for the state at large. The darker clay soil from the region of Acampo has more humus in the surface foot and but very little in the lower depths.

The humus of the Sheridan and Acampo soils is rich in nitrogen, but the quantity of humus itself is so small that the amount given to the soil is very little, and below the second foot was inappreciable.

The other soil is peculiar in having a humus that contains very little nitrogen in its third and fourth foot. As a consequence the soil itself is very poor in nitrogen.

All of these soils need good green-manuring with some nitrogen-rich legumes for several successive years to improve their texture and their productiveness.

Comparison by Classes.—The average percentages of humus in composite columns of soils of the same class gives an indication of what to expect in lands of these four classes.

TABLE 8.—AVERAGES OF HUMUS IN SOIL TYPES, SACRAMENTO VALLEY

Composite columns	Black adobe clay 4 columns	Stream alluvial loam 4 columns	Clay loam of plains 7 columns	Red mesa and bedrock 3 columns
Humus in first foot	1.16	1.47	.99	.47
Sum of, in upper 3 feet	2.41	3.54	2.40	.90
Sum of, in entire column	3.88	7.50	4.91	1.25
Nitrogen in humus—				
In first foot	5.56	5.51	4.68	8.58
Average in upper 3 feet	5.45	5.78	5.53	7.32
Average in entire column	4.96	6.46	5.03	6.29
Nitrogen in soil—				
In first foot	.06	.06	.05	.04
Average in upper 3 feet	.04	.07	.05	.02
Average in entire column	.02	.04	.02	.01

The figures speak for themselves, and show that the alluvial lands of the streams are richest in humus throughout and that the clay loams of the plains are next, while the black clay, in spite of its color, contains less humus in the upper three feet and in the entire column than the lighter colored plains soil. As a rule, the alluvial lands do not need green-manuring crops, but the others, and especially the red lands, would be greatly benefited thereby.

Nitrogen in Humus and Soil.—There is but little difference in the percentage of nitrogen in the humus of the upper three feet of each group, except that in the red soils the figures are highest; but for the entire column the alluvial lands stand at the head, with an average of 6.46 per cent.

For the soil itself the nitrogen is greatest in the stream alluvial, the average in the upper three feet being 0.07 per cent, or approximately 2800 pounds per acre-foot; this is but little more than the minimum amount (0.05 per cent) that is regarded as essential to fertility. Other groups contain less than the alluvial throughout.

SOIL COLUMNS OF THE SAN JOAQUIN VALLEY

San Joaquin Valley, with an area of eleven thousand square miles, possesses seven or more large and distinct soil types or regions, each of which is represented in our soil collection.

Twenty-four localities in eight counties were selected from which to secure columns of soil as nearly typical as possible of each region, and fifteen of the columns were taken to depths of

ten or twelve feet, the others being limited in depth either by hardpan, coarse gravel, or other obstruction which prevented the penetration of the soil auger; sometimes the water-table at depths of less than ten feet produced such a mushy condition in the soil as to prevent its being removed by the auger.

Gray Sandy Loams and Sandy Soils.—The greater part of the San Joaquin Valley is covered with a grayish sandy, and sandy loam, soil, usually deep and highly productive under irrigation or adequate rainfall. Some of them are highly charged with alkali salts in small areas, but these salts can be removed by proper means of irrigation and subdrainage. Calcareous and black alkali hardpans are also found occasionally, whose injurious effects can be corrected by proper treatment.

From these lands we selected seven localities in five counties from which to secure representative soil columns; three of these contained large amounts of alkali salts and are given a separate discussion. Each of the other columns was taken to a depth of eleven or twelve feet, from the following localities: two miles north of Exeter; three miles west of Tulare; one mile west of Modesto; and near Livingston; taken by Mr. F. J. Randolph.

The soil from west of Tulare has a little more than 1 per cent in the surface, and 2 per cent in the upper three feet, but the others in the table fall far below that percentage, the Modesto and Livingston soils being especially poor. Humus is found throughout the entire column from three of the localities, and contains fair percentages of nitrogen; but the actual amount in the soil itself is very small, except in the upper three feet of the Tulare column. The Livingston soil is little else than sand and is very poor in both humus and nitrogen.

Gray Clay-Loam Lands.—The lands of the west side of the San Joaquin Valley, derived from the rocks of the Coast Range and deposited from streams apparently more sluggish than came from the Sierras on the east, contain more clay and are of the clay-loam type of soil. They are more compact than are the sandy soils, and should, therefore, contain more humus than the latter. Three localities where the columns were obtained are on the west side of the valley, one mile south of Tracy, five miles southwest of Los Baños, and one mile west of Mendota.

TABLE 9.—HUMUS IN COLUMNS OF GRAY SANDY LOAMS AND SANDY SOILS, SAN JOAQUIN VALLEY

	TULARE COUNTY, EXETER				TULARE COUNTY, WEST OF TULARE				STANISLAUS COUNTY, MODESTO				MERCED COUNTY, LIVINGSTON			
	Soil Clay 12.17		Humus-Nitrogen in		Soil Clay 8.83		Humus-Nitrogen in		Soil Clay 8.19		Humus-Nitrogen in		Soil Clay 2.85		Humus-Nitrogen in	
Ft.		Humus	Humus	Soil		Humus	Humus	Soil		Humus	Humus	Soil		Humus	Humus	Soil
1	Sandy loam	.65	7.78	.05	Sandy	1.22	7.25	.09	Sandy	.37	6.43	.02	Sandy	.40	3.50	.01
2	Sandy loam	.40	10.53	.04	Sandy	.98	5.16	.05	Sandy	.27	5.18	.01	Sandy	.24	2.91	.01
3	Sandy loam	.32	7.02	.02	Sandy	.44	13.60	.06	Sandy	.19	5.16	.01	Sandy	.13	.....	....
4	Sandy loam	.30	5.62	.02	Sandy	.32	17.80	.06	Sandy	.18	5.44	.01	Sandy	.17	.....	....
5	Sandy loam	.25	4.49	.01	Sandy	.30	4.70	.01	Sandy	.17	5.76	.01	Sandy	.14	.....	....
6	Sandy loam	.24	5.27	.01	Sandy	.29	5.90	.02	Sandy	.18	5.25	.01	Hardpan	tr.	.....	....
7	Sandy loam	.23	4.88	.01	Sandy	.17	4.70	.01	Sandy	.17	4.94	.01	Sandy	....	.....	....
8	Sandy loam	.20	5.62	.01	Sandy	.17	5.30	.01	Sandy	.10	7.00	.01	Hardpan	....	.....	....
9	Sandy loam	.16	7.02	.01	Gray loam....	.09	3.70	tr.	Sandy	.08	8.75	.01	Sandy	....	.....	....
10	Sandy loam	.14	8.02	.01	Gray loam....	.08	.....	....	Sandy	.05	14.00	.01				
11	Sandy loam	.15	4.61	.01	Gray loam....	.07	.....	....	Sandy	.06	9.33	.01				
12					Gray loam....	.09	.....	....	Sandy	.07	10.00	.01				
Sum of per cents		3.04				4.22				1.87				1.08		
Average per foot		.28	6.44	.02		.35	7.54	.03		.15	7.25	.01		....	.....	....
*Upper 3 feet:**																
Sum of per cents		1.37				2.64				.83				.77		
Average per foot		.46	8.44	.04		.88	8.67	.07		.28	5.59	.01		.26	.....	....

* Range of most annual plant roots.

TABLE 10.—HUMUS IN COLUMNS OF GRAY CLAY LOAMS, SAN JOAQUIN VALLEY

	SAN JOAQUIN COUNTY SOUTH OF TRACY.				MERCED COUNTY LOS BANOS				FRESNO COUNTY NEAR MENDOTA		
Ft.	Soil Clay 17.03	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 15.02	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 24.91	Humus	$\frac{N}{H_u}$
1	Clay loam.....	1.35	5.20	.07	Clay loam.....	.68	8.64	.06	Clay loam.....	.55	7
2	Clay loam.....	.99	5.39	.05	Clay loam.....	.48	9.33	.05	Clay loam.....	.42	6
3	Clay loam.....	.83	4.06	.03	Clay loam.....	.44	3.82	.02	Clay loam.....	.38	7
4	Clay loam.....	.59	3.81	.02	Clay loam.....	.38	4.05	.02	Clay loam.....	.22	9
5	Clay loam.....	.41	4.11	.02	Clay loam.....	.34	4.94	.02	Clay loam.....	.17	9
6	Clay loam.....	.25	3.93	.01	Clay loam.....	.28	3.00	.01	Clay loam.....	.12	8
7	Clay loam.....	.16	3.51	.01	Clay loam.....	.30	5.60	.02	Clay loam.....	.22	4
8	Clay loam.....	.08	3.51	tr	Clay loam.....	.30	9.34	.03	Clay loam.....	.25	3
9	Clay loam.....	.10	2.81	tr.	Clay loam.....	.24	4.67	.01	Clay loam.....	.40	2
10	Clay loam.....	.10	2.81	tr.	Clay loam.....	.22	5.09	.01	Clay loam.....	.30	10
11	Clay loam.....	.10	.....	....	Clay loam.....	.22	6.37	.01	Clay loam.....	.28	2
12	Clay loam.....	.08	.....	....	Gravel	.....	.....	....	Clay loam.....	.19	3
Sum of per cents		5.04				3.88				3.45	
Average per foot		.42	3.91	.02		.32	5.90	.02		.29	5.
*Upper 3 feet:**											
Sum of per cents		3.17				1.60				1.35	
Average per foot		1.06	4.88	.05		.53	7.26	.04		.45	6.

* Range of most annual plant roots.

The Tracy soil is the only one of the above group which contains a fair amount of humus in the first foot and in the three upper feet. But in its lower depths it is much poorer than either that from Los Baños or Mendota. It is interesting to note the distribution downward in the two latter columns, which in the twelfth foot contain one-third of what is in the first foot. The lower six feet of the Los Baños column contains about one-half as much as the upper six feet, while in the Mendota column the upper and lower half are nearly equal in their percentages. The upper half of each column is much richer in nitrogen than the lower, as is the case with all California soils; but there are only traces in the lower six feet of the Tracy column. Deep rooting of plants is thus more favored in the Los Baños and Mendota soils and, with an increased supply of humus in the surface and abundant water, these soils should prove to be fully as productive as that from Tracy.

TABLE 11.—HUMUS IN COLUMNS OF GRAY ALKALI LANDS, SAN JOAQUIN VALLEY

	FRESNO COUNTY, CENTRAL COLONY				TULARE COUNTY, TULARE EXPERIMENT STATION				KERN COUNTY, MIRAMONTE				KINGS COUNTY, TULARE LAKE BED			
Ft.	Soil Clay 4.41	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 10.42	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 13.21	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 10.22	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1	"White Ash"	.45	7.44	.04	Sandy	.32	8.78	.03	Sandy loam	.25	5.05	.01	Dark sandy	.18	3.33	.01
2	Loam	.37	6.05	.02	Sandy	.39	5.04	.02	Sandy loam	.17	4.13	.01	Dark sandy	.10	1.00	tr.
3	Loam	.29	2.41	.01	Sandy	.40	4.21	.02	Sandy loam	.10	.....	....	Dark sandy	.14	.71	tr.
4	Whitish loam	.19	5.26	.01	Sandy	.28	5.01	.01	Sandy loam	.09	.....	....	Dark sandy	.17	.59	tr.
5	Whitish loam	.15	4.67	.01	Sandy	.12	7.02	.01	Sandy loam	.09	.....	....	Dark sandy	.18	1.67	tr.
6	Whitish loam	.07	.....	....	Sandy	.10	8.42	.01	Sandy loam	.06	.....	....	Dark sandy	.10	.....	....
7	Whitish loam	....	.....	....	Sandy	.10	7.02	.01	Sandy loam	.09	.....	....	Dark sandy	.08	.....	....
8	Whitish loam	....	.....	....	Sandy	.13	4.32	.01	Sandy loam	.05	.....	....	Dark sandy	.07	.....	....
9	Whitish loam	....	.....	....	Sandy	.06	.....	....	Sandy loam	.07	.....	....	Dark sandy	.08	.....	....
10	Whitish loam	....	.....	....	Sandy	.05	.....	....	Sandy loam	.05	.....	....	Dark sandy	.06	.....	....
11	Whitish loam	....	.....	....	Sandy	.06	.....	....	Sandy loam	.05	.....	...	Dark sandy	.05	.....	....
12	Whitish loam	....	.....	....	Sandy	....	.....	....	Sandy loam	.06	.....	....	Dark sandy	.04	.....	....
Sum of per cents		1.52				2.01				1.13				1.20		
Average per foot		.13	5.16	.02		.17	6.23	.01		.09	.....	....		.10	.....	....
*Upper 3 feet:**																
Sum of per cents		1.11				1.11				.52				.42		
Average per foot		.37	5.30	.02		.37	6.01	.02		.17	.....	....		.14	1.68	.01

* Range of most annual plant roots.

Gray Alkali Land.—The three columns of gray sandy and sandy loam valley soils, and the dark loam of Tulare Lake were found to contain high percentages of the several alkali salts, and, therefore, may be put in a class by themselves for consideration.

The "white ash" soil, so called because of its fine, light ashy and silty nature, was taken from near a vineyard in Central Colony, several miles southwest of Fresno, and is the representative of a large region lying on the north side of Kings River and reaching to within two miles of Fresno and eastward toward the foothills of the Sierras. The soils are rich and have been largely devoted to grape-growing. The water-table was reached at a depth of four feet, the soil assuming a white color and, below the sixth foot, losing all traces of humus.

The Tulare column was obtained from the old experiment station tract in a spot where all vegetation had been killed by the alkali salts.

The Tulare Lake column was taken a number of years ago from the bed of the lake, which had long been dried-out to many feet in depth.

The column from Miramonte, fifteen miles west of Wasco, represents what seems to be a belt of low lands or what was once a slough connecting the Tulare Lake with Buena Vista and Kern lakes; in this belt southward the alkali of the lakes had accumulated to great depths. The alkali consists chiefly of the sulfates and chlorids (glaubers and common salt), and in this column was distributed at the rate of one-half of one per cent per foot, giving a total approximating 233,000 pounds for the twelve feet per acre. No vegetation other than scattering alkali weeds was seen.

Analysis of the upper four feet of each of these columns gives the following percentages of alkali salts calculated also to pounds per acre.

TABLE 12.—ALKALI SALTS IN THE UPPER FOUR FEET OF THE COLUMNS

	Percentage in Soil				Pounds per acre; approximate			
	Sulfates	Carbonates	Chlorids	Total	Sulfates	Carbonates	Chlorids	Total
Tulare	.03	.04	.02	.09	4,800	6,400	3,200	14,400
Central Colony	.25	.09	.01	.35	40,000	14,400	1,600	56,000
Miramonte	.55	.02	.09	.66	88,000	3,200	14,400	105,600
Tulare Lake bed	.13	.07	.07	.27	20,800	11,200	11,200	43,200

The Fresno and Tulare soils have been under cultivation for the past few years and the alkali has been kept below the surface; as a consequence, root growth was greater and its decay and humification produced more humus than in the Miramonte and Tulare Lake soils. There was also less of alkali salts.

The percentage of humus in the first foot of each of the columns, except that of the lake, is not very much lower than in other gray soils of the Tulare plains. It is distributed through the entire column, except in the water-soaked lower part of the white-ash lands, and the total amount is greater than in some of the alkali-free columns of the valley.

The results, then, apparently show that neither carbonate, sulfate, or chlorid of soda have any injurious effect on humus itself, but that they do so retard or even kill the growth of surface plants and root systems as to cut off the supply of humus-forming material. The humus in the Tulare Lake bed column is exceptionally low in nitrogen from some cause not now apparent, and in all of the soils the nitrogen percentage falls below the minimum required for fertility.

The conclusion is plain, then, that where a green-manure crop can be grown by keeping the injurious alkali salts below a depth of three or more feet by irrigation its conversion to humus under favorable condition is not interfered with.

Black Adobe Clay and Loam Lands.—A large area of black adobe land occupies a region in San Joaquin County extending from two miles north of Calaveras River south to French Camp slough and from the tules or marshes of San Joaquin River eastward toward the hills, and is timbered with oaks. The character of the soil is shown in a column twelve feet in depth taken two and one-half miles southeast of Stockton.

The region continues southward in a narrow belt along the base of the hills into Kern County, being known in Tulare County as "dry bog" because of its tendency to break up into small fragments when dry. It is here underlaid by a reddish clay loam, from which it is sometimes separated by a whitish calcareous and silicious lime and magnesia bed of varying thickness. Two columns of this black clay adobe were secured from near Porterville; one is from the Williams orchard with a depth

TABLE 13.—HUMUS IN COLUMNS OF BLACK CLAYS AND LOAMS, SAN JOAQUIN VALLEY

	SAN JOAQUIN COUNTY SOUTHEAST OF STOCKTON				SAN JOAQUIN COUNTY WEST OF TRACY				TULARE COUNTY SOUTH OF PORTERVILLE				TULARE COUNTY WEST OF TULARE			
Ft.	Soil Clay 56.53	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 38.80	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 29.94	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 12.89	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1	Black clay....	1.16	7.00	.08	Black clay....	.82	5.10	.04	Black clay....	1.20	3.04	.04	Black loam..	1.16	6.72	.08
2	Black clay....	.76	7.38	.06	Black clay....	.70	5.59	.04	Black clay....	1.00	4.91	.05	Black loam..	.62	9.03	.06
3	Black clay....	.50	7.84	.04	Black clay....	.30	2.50	.01	Black clay....	.83	5.58	.05	Black loam..	.25	8.80	.02
4	Gray clay	.22	14.00	.03	Gray clay	.12	1.69	.01	Marly clay ..	.23	7.33	.02	Black loam..	.16	.....	....
5	Gray clay	.22	8.91	.02	Gray clay	.19	.....	....	Red loam	.12	10.53	.01	Sandy	.11	.....	....
6	Gray clay	.18	3.11	.01	Gray clay	.09	.....	....	Red loam	.06	14.04	.01	Sandy	.09	.....	....
7	Gray clay	.11	.....	....	Gray clay	tr.	.....	....	Red loam	....	.....	....	Sandy	.09	.....	....
8	Gray clay	.09	.....	....	Gray clay	....	.....	....	Red loam	....	.....	....	Sandy	tr.	.....	....
9	Gray clay	.08	.....	....	Gray clay	....	.....	....	Red loam	....	.....	....	Sandy	....	.....	....
10	Gray clay	.07	.....	....	Gray clay	....	.....	....	Red sandy....	....	.....	....	Coarse sand	....	.....	....
11	Gray clay	.09	.....	....	Gray clay	....	.....	....	Red sandy....	....	.....	...	Coarse sand	....	.....	....
12	Gray clay	.11	.....	....	Gray clay	....	.....	....	Sandy	....	.....	....	Coarse sand	....	.....	....
Sum of per cents		3.59				2.22				3.44				2.48		
Average per foot		.29	.....	....		.19	.....	....		.29	.....	....		.21	.....	....
*Upper 3 feet:**																
Sum of per cents		2.42				1.82				3.03				2.03		
Average per foot		.81	7.40	.06		.61	4.30	.03		1.01	4.50	.05		.64	8.18	.05

* Range of most annual plant roots.

of seven feet; the other which appears in the table of analyses is from the Henderson orchard and twelve feet in depth.

On the west side of the valley another narrow black adobe belt reaches along the base of the hills from west of Tracy into Merced County on the south. It is represented by a column of ten feet taken three miles west of Tracy.

Still another belt of black land, not so clayey as the others, though containing from 12 to 14 per cent of clay, lies three miles west of Tulare; a column was taken from it.

It is a matter of much surprise that these clay soils with their very black color should have so small a percentage of humus, the maximum of which is but 1.2 per cent, found in the soil from Porterville. We would naturally anticipate finding fully 10 per cent, and yet in the Tracy soil there is less than 1 per cent. It is evident that the necessary conditions of moisture and warmth for the humification of the vegetable material are not present in these very close, compact clays. The Porterville soil is subjected to irrigation several times annually, while that from Tracy is not, and this may account for the larger amount of humus in the former. In the Stockton column the humus is found to the full depth of twelve feet, while in the others it was found only in the upper six feet.

The nitrogen content of the Stockton soil is good in the upper foot and fair for the three feet, the humus itself being rich in nitrogen, but in the other columns it is quite low and suggests the need of an additional nitrogen supply, either through green-manuring or artificial fertilization.

Reddish Clay Lands.—A prominent and wide region of lands of this character occupies a large part of the eastern side of the valley: it is narrow on the north in San Joaquin, Stanislaus, Merced, and Madera counties, and on the south in Tulare and Kern, but quite wide in Fresno County. It is the southern extension of the belt of "bedrock" lands of Sacramento Valley. It is largely characterized by a rocky hardpan of cemented gravel and grit, with thicknesses of an inch to as much as twelve inches and even more, occurring at depths of from two to six or eight feet below the surface. When it occurs near the surface the hardpan gives rise to a rolling or hogwallow feature. An excel-

TABLE 14.—PERCENTAGES OF HUMUS IN COLUMNS OF RED VALLEY LANDS, SAN JOAQUIN VALLEY

	SAN JOAQUIN COUNTY FARMINGTON				FRESNO COUNTY EAST OF FRESNO				FRESNO COUNTY KEARNEY PARK				TULARE COUNTY LINDSAY			
Ft.	Soil Clay 26.90	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 11.01	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 14.62	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 8.52	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1	Brown clay....	2.04	6.61	.14	Red loam	.85	4.94	.04	Red loam	.66	6.81	.05	Red loam	.27	8.74	.01
2	Brown clay....	1.74	7.10	.12	Red loam	.70	5.00	.04	Red loam	.30	10.33	.03	Red loam	.20	5.00	.01
3	Brown clay....	1.16	9.66	.11	Red loam	.32	5.32	.02	Red loam	.22	10.00	.02	Red loam	.13	6.15	.01
4	Brown clay....	.64	5.27	.03	Loam	.29	2.76	.01	Red loam	.25	11.20	.03	Red loam	.11	7.27	.01
5	Light red clay	.57	4.93	.03	Loam	.56	.....	....	Red loam	.25	10.60	.03	Reddish loam	.11	5.50	.01
6	Light red clay	.51	5.51	.03	Loam	.16	.....	....	Red loam	.26	10.60	.03	Reddish loam	.12	5.63	.01
7	Light red clay	.43	5.86	.03	Loam	....	.....	....	Red loam	.14	14.30	.02	Reddish loam	.07	8.57	.01
8	Light red clay	.40	5.62	.02	Loam	....	.....	....	Red loam	.08	17.50	.01	Reddish loam	.06	10.00	.01
9	Light red clay	.27	6.24	.02	Loam	....	.....	....	Red loam	.07	.....	....	Hardpan	....	.....	....
10					Loam	....	.....	....	Red loam	.10	.....	....				
11									Coarse gravel	....	.....	....				
12									Coarse gravel	....	.....	....				
Sum of per cents		7.76				2.88				2.34				1.07		
Average per foot		.85	6.30	.06		.28	.....	....		.23	11.47	.03		.13	6.46	.01
*Upper 3 feet:**																
Sum of per cents		4.94				1.87				1.16				.60		
Average per foot		1.65	7.60	.12		.62	5.10	.03		.39	9.05	.03		.20	4.96	.01

* Range of most annual plant roots.

lent soil underlies the hardpan, however, and when the latter is broken up by dynamite good results in tree growth are usually obtained.

Columns of this land were obtained from the Butler vineyard a few miles east of Fresno; from the Kearney Park west of Fresno; from Lindsay in Tulare County; and from the place of H. Mueller two miles southwest of Farmington, San Joaquin County. The latter perhaps more properly belongs to the adobe group, though lighter in color.

These lands differ somewhat in their content of clay, that from Farmington being of a clay nature and the other sandy loams. The soil from Farmington contains good humus percentages in the three upper feet and throughout the entire column of ten feet, but each of the other localities shows a deficiency in the surface foot, and throughout the entire depths. In the soil from east of Fresno a hardpan layer was struck in the sixth foot, but was broken up and the soil below it was obtained; no humus was found below the hardpan.

The high humus of the upper three feet of the Farmington column and its high nitrogen content gives to the soil an excellent nitrogen percentage of 0.12 per cent, or approximately 14,000 pounds of organic nitrogen per acre within the range of most plant roots. Bacterial activity in this soil will do much to promote an abundant nitrogen supply for plants and consequent high fertility. The humus of the Kearney Park soil is rich in nitrogen throughout, but the small amount of humus in each foot from the surface down gives but a small amount to the soil, the average for each foot being 0.03 per cent, or about 1200 pounds per acre. The other soil columns are also low in their nitrogen content.

Delta Plains of Kings and Kern Rivers.—There are two tracts of this class of lowlands which are made of fine sediment brought down from the Sierra Nevada, the Coast Range on the west contributing little or nothing to these deltas as its streams mainly discharge their sediments westward to the Pacific.

The Mussel Slough region bordering the Tulare Lake receives its sediment from the Kings, Kaweah, and Tule rivers, and covers a very large area. It is timbered with oaks, and the nature

of its soils are shown in columns twelve feet deep taken respectively from near Corcoran and Armona by Mr. F. E. Johnson.

The Kern River delta farther south, with an area of about 290 square miles, is also timbered with oaks. It is represented in the soil collection by a column taken three miles southwest of Bakersfield. Water was reached in the seventh foot.

TABLE 15.—HUMUS IN COLUMNS OF DELTA LANDS, SAN JOAQUIN VALLEY

	KINGS RIVER DELTA							KERN RIVER DELTA		
	KINGS COUNTY ARMONA			KINGS COUNTY CORCORAN				KERN COUNTY SOUTH OF BAKERSFIELD		
Ft.	Soil Clay 6.42	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 15.11	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 11.28	Humus	Humus-Nitrogen in Humus
1	Sandy	.46	6.66	.03	Dark loam	.51	8.26	.04	Loam	1.46	4.7
2	Sandy	.32	7.02	.02	Dark loam	.24	7.02	.02	Loam	.71	6.2
3	Sandy	.22	7.66	.02	Dark loam	.24	8.19	.02	Loam	.32	6.5
5	Sandy	.16	7.02	.01	Gray loam	.24	9.36	.02	Loam	.18	6.11
4	Sandy	.20	7.72	.02	Gray loam	.11	7.66	.01	Loam	.40	5.5
6	Reddish loam	.18	6.24	.01	Gray loam	.05	.....	....	Loam	.20	4.6
7	Reddish loam	.24	7.02	.02	Gray loam	.06	.....	....	Loam	.26	4.2
8	Reddish loam	.18	6.24	.01	Gray loam	.05	.....	....			
9	Reddish loam	.20	7.02	.02	Gray loam	.06	.....	....			
10	Reddish loam	.16	7.02	.01	Gray loam	.06	.....	....			
11	Reddish loam	.16	7.02	.01							
12	Reddish loam	.16	7.02	.01							
Sum of per cents		2.64				1.62				3.63	
Average per foot		.22	6.98	.02		16	8.10	.02		.52	5.5
*Upper 3 feet:**											
Sum of per cents		1.00				.99				2.49	
Average per foot		.33	7.10	.02		.33	7.82	.03		.83	5.9

* Range of most annual plant roots.

It was anticipated at the outset that the delta loams of the Tulare Lake and Bakersfield regions would be rich in humus in at least the upper feet, because of their surface vegetation of grasses and weeds and fallen leaves. But humification of these has not taken place thoroughly, and we find that the amount of humus in the upper three feet is not so large as in the sandy loam soils of the plains. The surface soil of the Kern delta is the richest in humus, which gives to the soil its per cent of

nitrogen, but in the three upper feet of each of the columns both humus and nitrogen are below the minimum for fertility.

River Alluvial Lands and Tule Marshes.—The rivers of the San Joaquin Valley are usually bordered by narrow bottom lands, the Merced and Kings rivers being exceptions where they enter the valley plains. A column of eight feet depth was taken by Mr. F. E. Johnson from the land of Kings River near Kings River Post Office, and is the only representative of such lands from this valley. The surface soils of other streams have, however, been examined from time to time and their humus content ascertained.

The tule marshes cover a very large region at the junction of the San Joaquin and Sacramento rivers and are divided up into "islands" by many sloughs. The soils of these islands is shallow and peaty though rich, and water appears at but a few feet below the surface. There are localities, however, where a deep soil may

TABLE 16.—HUMUS IN COLUMNS OF LOWLAND SOILS, SAN JOAQUIN VALLEY

	River Alluvial Fresno County Kings River P. O.				Tule Marsh San Joaquin County Stockton			
Ft.	Soil Clay 4.58	Humus	Humus-Nitrogen in Humus	Soil	Soil	Humus	Humus-Nitrogen in Humus	Soil
1	Sandy	1.29	4.25	.06	Black loam	14.10	5.85	.83
2	Sandy	.77	4.38	.03	Black loam	19.15	4.82	.94
3	Sandy	.44	4.47	.02	Very black loam	16.50	5.20	.85
4	Sandy	.33	3.83	.01	Very black loam	13.00	4.41	.57
5	Sandy	.31	3.62	.01	Lighter loam	6.92	4.94	.34
6	Sandy	.17	4.97	.01	Lighter loam	2.96	4.35	.13
7	Sandy	.17	4.13	.01	Lighter loam	2.12	5.80	.12
8	Sandy	.19	3.72	.01	Lighter loam	4.28	5.09	.22
9					Clay	1.44	10.14	.15
10					Clay	.36	2.33	.01
11					Clay	.34	2.06	.01
12					Clay	.28	6.07	.01
Sum of per cents		3.67				81.75		
Average per foot		.30	4.16	0.2		6.81	5.10	.35
*Upper 3 feet:**								
Sum of per cents		2.50				50.05		
Average per foot		.83	4.40	.04		16.68	5.30	.88

* Range of most annual plant roots.

be found, and from one of these a column of twelve feet was obtained for us by Mr. W. W. Mackie, then of the United States Bureau of Soils. It was taken from a few miles northwest of Stockton and is an excellent representative of these lands.

The river alluvial is not especially rich in either humus or organic nitrogen, though one would suppose from its alluvial character that the amount of vegetable material in it would be great.

The tule or swamp lands near Stockton have to a large extent been reclaimed by dykes, by pumping out the water, and by protection from overflow. They contain a very large percentage of decayed vegetable matter consisting of tule roots, etc., and this has been quite largely humified, as shown by the tables, especially in the upper four feet. Below this depth the amount suddenly drops from 13 per cent in the fourth to 6.9 per cent in the fifth foot, and from 1.4 per cent in the ninth to 0.36 per cent in the tenth foot. No other tule soil in the state that has been examined contains so high a percentage of humus and organic nitrogen, probably because of extra favorable conditions of warmth and moisture and excess of vegetable matter in the Stockton column. This large amount of humus produces acid soils, and liming is necessary to render them neutral and productive. The 0.83 per cent of humus nitrogen in the surface soil is very great, being equivalent to an average of 25,000 pounds per acre. There is a still greater percentage in the second foot as well as in the third; but below the latter it falls off rapidly to the minimum of 0.01 per cent in the tenth foot.

Comparison of San Joaquin Valley Soils of Different Types

The table below gives in a concise form the relative percentages of humus and nitrogen in the eight soil types of the San Joaquin Valley, and from it we can make comparisons more easily than from a study of the soil columns themselves. The types are placed in the order of highest to lowest composite averages of humus in the first foot, and there is almost the same succession in the combined upper three feet and the entire column respectively.

TABLE 17.—PERCENTAGES OF HUMUS AND NITROGEN ACCORDING TO SOIL TYPES, SAN JOAQUIN VALLEY

	Tule marsh 1 col.	Stream alluvial 1 col.	Black clays 4 col.	Red lands 4 col.	Delta lands 3 col.	Valley loams 7 col.	Alkali lands 3 col.	Lake bed 1 col.
Humus—								
Per cent in first foot	14.10	1.29	1.09	.95	.81	.75	.34	.18
Sum of, in upper 3 feet	50.05	2.50	2.32	2.15	1.49	1.68	.91	.42
Sum of, in entire column	81.75	3.67	2.93	3.51	2.63	3.13	1.58	1.20
Average per foot in upper 3 feet	16.68	.83	.82	.72	.49	.56	.30	.14
Average per foot in entire column	6.81	.30	.25	.32	.22	.27	.12	.10
Nitrogen in Humus—								
Average in first foot	5.85	4.25	5.46	5.52	6.38	6.56	7.09	3.33
Average in upper 3 feet	5.30	4.40	6.09	6.72	6.93	6.09	5.30	1.68
Average in entire column	5.10	4.16	7.10	7.06	6.85	6.10	5.33	1.46
Nitrogen in Soil—								
Average in first foot	.83	.06	.06	.06	.04	.05	.03	.01
Average in upper 3 feet	.88	.04	.04	.05	.03	.04	.02	.01
Average in entire column	.35	.02	.03	.03	.02	.02	.01	.01

There are large differences in the amount of humus in the several groups, as is to be expected from soils of such extremely different characters, the highest percentage being in the Stockton tule marshes and the lowest in the strong alkali lands and in the Tulare Lake bed.

The surface soils of the valley are not rich in humus as a rule, and this is well shown in these tables. Even the black clays and loams, which because of their color would be supposed to contain high percentages, were found to have but little more than 1 per cent, and in some instances less than that. Similarly the alluvial and delta soils of Kings and Kern counties are very low in humus. The tule marshes in the region of Stockton are naturally rich, because of the great amount of vegetable matter such as roots and leaves that have accumulated in them, and we find as much as 14 per cent of humus in the first foot and 19 per cent in the second.

Humus and Nitrogen in the First Foot.—The general average of humus in the surface soils of the state is 1.25 per cent, and it thus appears that the soils of the San Joaquin Valley fall much below that. In but eight of the columns (omitting the Stockton tule) is there as much as 1 per cent in the surface foot, the

highest being found in the brownish lands of Farmington, and the lowest of 0.18 per cent in the soil of Tulare Lake bed. The general average of all is 0.80 per cent, which is much below the requirements for good texture and productiveness.

The humus of the surface foot contains for the most part a fair percentage of nitrogen, the general average being 5.98 per cent, but there are several soils in which the humus is very poor, and a high amount of such humus is necessary to give to the soil an amount adequate for fertility. It is thought that a fertile soil should not have less than 0.05 per cent of organic or humus nitrogen in the surface foot, and from the tables it is seen that because of the small amount of humus, many of the soils have much less than 0.05 per cent.

The soil richest in nitrogen in the above group is that from Farmington which, because of the abundance and richness of its humus, has 0.14 per cent of nitrogen, equivalent to more than 5000 pounds per acre-foot. The sandy soils of the sandy and black loam plains west of Tulare and the black clay southeast of Stockton each contains from 3000 to 3500 pounds of humus nitrogen per acre-foot.

The humus of the Stockton tule soil contains a fair amount of nitrogen, and the very high percentage of the former gives to the soil the enormous amount of 0.83 per cent of nitrogen, or approximately 32,000 pounds of humus nitrogen per acre-foot. The second foot is even richer.

Humus in the Upper Three Feet.—The range of annual plant roots in California soils is in the upper three feet, and this may be considered as the true soil. This combination of three feet more than doubles the amount of humus and its nitrogen that is to be regarded as directly influencing fertility, though the average per foot is lessened. The distribution through the three feet is of greater advantage than if concentrated in the upper foot, for the roots thus secure their nitrogen in a moister soil and away from the heated surface. The general average summation of humus in this depth of three feet for all of the columns, omitting the Stockton tule, is 1.78, or 0.66 per cent per foot, and this is about one-third less than for the state at large. The humus is however fairly rich in nitrogen (6.22 per cent)

and had the former been more abundant the percentage given to the soil would have been sufficient for needs of crops.

Humus and Nitrogen in the Entire Column.—Humus was found to occur to depths of ten or twelve feet in but thirteen of the columns. In the brown land of Farmington and the alluvial soil of Kings River it would clearly have been found at that depth had the columns been taken to twelve feet. On the other hand, in five of the ten-foot or twelve-foot columns humus was not found in the lower four or five feet. The percentages diminished downward from the first foot in all cases, in some instances very sharply, and usually added but little to the combined percentage of the upper three feet. The Farmington column with its 7.76 per cent of humus is the richest group (excepting the Stockton marshes), followed by the Tracy loam and Tulare plains soils. Twelve of the columns have higher total amounts of humus than the average of several hundred soils of the humid region, and doubtless the total amount of organic nitrogen in these soils is also greater than that in the humid.

The humus not only varies in its percentage of nitrogen in each of the twenty-five localities from which the soils were taken, but also in the several depths below the surface in each column. It is poorest in the Tulare Lake bed and richest throughout the column from Kearney Park, where each foot except the first contains more than 10 per cent. It is only occasionally that among other columns is there found a humus having as much as 10 per cent. The general average of all is but 6.22 per cent, a figure too low to benefit the soil greatly except where the humus content is above 1 per cent.

The sandy loams of the plains which comprise the greater part of the San Joaquin Valley and the red lands of the eastern side of the valley are but slightly different in their general averages of humus, the latter, because of the high percentages in the Farmington clay, having slightly more throughout its column. The surface soils are clearly in need of green-manure crops that will supplement that humus already present. The soils are liable to form surface crusts where there is so little humus present, and require special care and treatment to prevent injury.

The humus of both plains and the red lands is fairly rich in nitrogen; but the amount for the soil itself is below the normal of 0.05 per cent minimum, except in the first foot. These lands therefore need not only more humus but a humus that is very rich in nitrogen. A leguminous crop, such as the spring vetch, should alone be used for humification, for by it the land secures a greater amount of green stuff, a far greater amount of nitrogen than if grass, rye, or alfileria were used, and such nitrogen is derived chiefly from the atmosphere.

SOIL COLUMNS OF THE LOWER FOOTHILLS OF SIERRA NEVADA

The lower foothills of the Sierra Nevada rising from the valley plains to an elevation of 2500 feet above sea-level forms an important fruit-bearing region. The soils derived from slate and granite are often shallow on the hillsides but deep in the valleys.

TABLE 18.—HUMUS IN SOIL COLUMNS OF FOOTHILLS

	BUTTE COUNTY PALERMO				PLACER COUNTY NEWCASTLE				AMADOR COUNTY EXPERIMENT STATION, JACKS		
Ft.	Soil Clay 17.80	Humus	Humus-Nitrogen in Humus	Soil	Soil Clay 14.17	Humus	Humus-Nitrogen in Humus	Soil	Soil Clay 16.43	Humus	Humus-Nitrogen in Humus
1	Red clay.....	.96	5.85	.06	Reddish loam	1.35	7.45	.10	Red loam	1.07	4.50
2	Red clay.....	.36	3.05	.01	Reddish loam	1.24	9.72	.12	Red loam	.54	5.20
3	Gravelly clay	.20	3.00	.01	Reddish loam	1.18	6.37	.08	Red loam	.35	3.51
4	Gravelly clay	.22	3.64	.01	Reddish loam	.60	12.50	.08	Red loam	.35	3.61
5	Lighter clay..	.12	.....	....	Reddish loam	.16	8.76	.01	Red loam	.25	3.37
6	Lighter clay..	.10	.....	....	Gravelly clay	.18	8.32	.02	Granitic clay	.14	4.01
7	Lighter clay..	.10	.....	....	Gravelly clay	.34	7.95	.03	Granitic clay	.10	4.21
8					Gravelly clay	.26	9.63	.03	Granitic clay	.06	4.73
9					Gravelly clay	.08	.....	....			
10					Gravelly clay	.12	.....	....			
11					Gravelly clay	.07	.....	....			
12					Gravelly clay	.06	.....	....			
Sum of per cents		2.06				5.64				2.86	
Average per foot		.29	3.91	.02		.47	8.84	.06		.36	4.16
*Upper 3 feet:**											
Sum of per cents		1.52				3.77				1.96	
Average per foot		.51	3.97	.02		1.26	7.80	.10		.65	4.44

* Range of most annual plant roots.

Columns of the red slate soil were taken from Palermo, Butte County, and from the former experiment station tract near Jackson, Amador County; also from a bluff near Newcastle, Placer County, taken by Mr. Paul H. Steude of Newcastle.

The red clay soils of Jackson and Palermo are quite similar in the amount of humus in the first foot, but the former is the richer below that. The clay is quite close and compact, and this has prevented the development of roots to the extent permitted by the looser gravelly granitic soil of Newcastle, in which there is more humus. The general average of humus in the first foot is 1.12 per cent; that of thirty-one soils of the foothills previously examined is 1.05 per cent, although it is found to be higher in the valleys farther up in the mountains, in the regions of Auburn, Grass Valley, Nevada City, and Placerville, than near the Sacramento Valley. In percentage summation the general average of the upper three feet of the columns is .80 per cent.

The humus in each of the Palermo and Jackson soils is very poor in nitrogen, not only in the upper three feet but in the entire column; and the nitrogen of the respective soils is also below the normal. On the other hand, the humus in the soil from Newcastle is far richer in nitrogen, there being as much as 8.8 per cent in the humus of each foot of the twelve-foot column. The soil itself contains 0.10 per cent in the upper three feet, which is much above the normal, and is equivalent to about 4000 pounds for each foot in depth per acre.

SOIL COLUMNS OF THE COAST RANGE VALLEYS

The Coast Range of mountains, reaching from the Oregon state line south to the Mexican border, has but few agricultural possibilities except in the many valleys enclosed between the mountain ridges. The country north of Mendocino County is especially rugged and the valleys are few, but southward there are many valleys that present splendid agricultural attractions, and we have endeavored to have the soils of the largest and most important ones represented in the columns of this series. Of course, it must be understood that in each valley there are a number of soil variations and gradations from the hills to the lower valley center, and that the column has been selected to

represent the best and most extensive of these, the object being to ascertain to what depth and in what percentage the humus reaches under favorable conditions.

Fifteen valleys in nine counties north of the Santa Ynez Mountains have their soils represented in the series of columns, and in the accompanying tables are arranged in order of occurrence from north to south.

We may conveniently follow the usual subdivision of the Coast Range counties and arrange the table into the counties *north* of San Francisco Bay, embracing seven soil columns; the *bay region* itself, embracing the country east and west of the bay as far south as San José, represented by eight soil columns; and the counties *south* of the bay as far as Santa Barbara, represented by nine soil columns.

North of the Bay Region

The valleys represented in this section of the Coast Range are Russian River, Santa Rosa, Los Guilloeos, Sonoma, Napa, and Vaca: there are other important though much smaller ones east and west of these and in the counties further north, from which we were unable to secure columns.

Russian River Valley.—The soil columns from this valley were taken from the alluvial lands of the hop fields belonging to Mr. T. Boone Miller, six miles south of Healdsburg, and from the red hills three miles southwest of Healdsburg, Sonoma County.

Santa Rosa Valley.—The western part of the valley has a heavy adobe soil, which is not so largely in cultivation as the more loamy land of the eastern and middle part. A column of twelve feet depth was taken from the creek alluvial on the Vrooman orchard east of Santa Rosa.

Los Guilloeos Valley.—This valley is not very wide nor long, and it opens northward into Santa Rosa Valley. Its soil is a reddish loam and is represented by a column taken a short distance southeast of Kenwood, Sonoma County.

Sonoma Valley.—The valley opens southward to San Francisco Bay and is largely covered by marsh lands, but the northern

part is higher and comprises better lands. A black adobe clay seems to be the prevailing soil and a column of this was taken near the village of El Verano.

Napa Valley.—The soil is chiefly loamy in nature, interspersed with some adobe belts on either side. A column of the former was obtained near Yountville, Napa County, to a depth of twelve feet.

Vaca Valley.—This valley is situated among the foothills on the west side of the Sacramento Valley, into which it opens, and is noted for its early fruits. The soil is chiefly a reddish loam, as shown in the column obtained southeast of Vacaville.

These valleys are characterized by having a high humus percentage in the upper foot and also in the four feet which is the usual range of plant roots. The soil from Yountville, Napa Valley, is the richest of the group, and contains nearly 6 per cent of humus in the upper three feet. The Kenwood and El Verano soils are the next in humus content, each containing more than 2 per cent in the first foot and more than 5 per cent in the upper three feet, the range of most plant roots. A notable feature in four of the columns—Russian River, Santa Rosa, El Verano, and Yountville—is that there is more than 1 per cent in each of the upper four feet; in the Santa Rosa column that percentage is found in six feet and almost in the seventh foot. The distribution of humus downward through the entire column of twelve feet is good, the average for the Russian River alluvial being more than 1 per cent for each foot, while the Santa Rosa and Yountville averages very nearly equal it. This is a splendid record and places these soils among the best in the state.

The humus of the Kenwood soil is richer in nitrogen than that of any other column, the average being 10.61 per cent for the seven feet. That of the Santa Rosa has an average of 5.87 in its twelve feet. The richness of the Kenwood soil is chiefly in its lower fourth, fifth, and sixth feet. The humus of the El Verano adobe is for some reason or other weaker in nitrogen than any other (except in its first foot), the general average being but 2.67 per cent in each foot.

The most important consideration, however, is the amount of humus nitrogen occurring in the soil, and we find it to be highest

TABLE 19.—HUMUS IN SOIL COLUMNS NORTH OF THE BAY REGION

Ft.	Russian River Valley, Sonoma County, South of Healdsburg — Soil Clay 18.13	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Healdsburg Hills, Sonoma County, Southwest of Healdsburg — Soil Clay 15.41	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Santa Rosa Valley, Sonoma County, East of Santa Rosa — Soil Clay 13.33	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Los Guilocos Valley, Sonoma County, Kenwood — Soil Clay 26.23	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1	Alluvial	1.76	4.47	.08	Red loam	1.86	4.24	.08	Loam	1.95	4.75	.09	Loam	2.25	5.60	.13
2	Alluvial	1.64	4.00	.06	Red loam	1.00	4.20	.04	Loam	1.53	5.32	.08	Loam	1.95	5.28	.10
3	Alluvial	1.34	3.77	.05	Red loam	.72	5.13	.04	Loam	1.03	7.09	.07	Loam	1.01	6.47	.07
4	Alluvial	1.24	3.62	.05	Red loam	.53	3.58	.02	Loam	1.36	5.58	.08	Loam	.63	18.10	.11
5	Alluvial	1.14	4.06	.05	Red loam	.34	4.11	.01	Loam	1.23	5.48	.07	Loam	.39	10.25	.04
6	Alluvial	.89	3.81	.03	Red loam	.26	3.07	.01	Loam	1.09	4.64	.05	Loam	.22	23.20	.05
7	Alluvial	.84	4.01	.03	Red loam	.14	2.85	.01	*Loam*	.91	5.25	.05	*Loam*	1.64	5.36	.09
8	Alluvial	.80	3.71	.03	Yellow loam	.07	.....	....	Loam	.64	6.14	.04	Gravel	.....	.....	....
9	Alluvial	.77	3.30	.03	Yellow loam	.07	.....	....	Loam	.43	7.18	.03				
10	Alluvial	.57	2.96	.02	Yellow loam	.08	.....	....	Loam	.41	7.19	.03				
11	Alluvial	.63	3.34	.02	Yellow loam	tr.	.....	....	Loam	.27	6.24	.02				
12	Alluvial	.66	3.19	.02					Loam	.25	5.62	.02				
Sum of per cents		12.28				5.07				11.10				8.10		
Average per foot		1.01	3.70	.04		.46	3.89	.03		.92	5.87	.05		1.16	10.61	.08
*Upper 3 feet:**																
Sum of per cents		4.74				3.58				4.51				5.21		
Average per foot		1.58	4.08	.06		1.19	4.50	.05		1.50	5.72	.08		1.74	5.80	.10

* Range of most annual plant roots.

TABLE 19.—HUMUS IN SOIL COLUMNS NORTH OF THE BAY REGION—(*Continued*)

SONOMA VALLEY
SONOMA COUNTY
EL VERANO

Ft.	Soil Clay 29.02	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1	Black clay	2.14	4.91	.11
2	Black clay	1.63	1.47	.02
3	Black clay	1.35	2.59	.04
4	Black clay	1.29	3.88	.05
5	Reddish clay	.79	2.53	.02
6	Reddish clay	.69	4.06	.03
7	Reddish clay	.52	1.54	.01
8	Reddish clay	.84	1.25	.01
9	Reddish clay	.60	1.67	.01
10	Reddish clay	.40	2.75	.01
11	Gravel	....	.....	....
12				
Sum of per cents		10.05		
Average per foot		1.00	2.67	.03
*Upper 3 feet:**				
Sum of per cents		5.12		
Average per foot		1.71	3.00	.05

NAPA VALLEY
NAPA COUNTY
YOUNTVILLE

Soil Clay 18.60	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
Loam	2.64	4.25	.11
Loam	2.02	4.46	.09
Loam	1.28	3.78	.04
Loam	1.18	2.94	.03
Loam	.80	3.13	.03
Loam	.90	3.12	.03
Loam	.88	2.94	.02
Loam	.64	2.66	.02
Loam	.36	3.61	.01
Loam	.28	3.57	.01
Loam	.30	3.68	.01
Loam	.32	3.45	.01
	11.38		
	.95	3.46	.03
	5.94		
	1.98	4.18	.08

VACA VALLEY
SOLANO COUNTY
VACAVILLE

Soil Clay 18.02	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
Loam	1.97	6.39	.13
Loam	.99	6.35	.06
Loam	.71	5.90	.04
Loam	.82	4.04	.03
Loam	.83	4.34	.04
Loam	.68	2.88	.02
Loam	.45	3.11	.01
Loam	.23	8.08	.01
Loam	.48	8.12	.04
Loam	.59	4.23	.03
Loam	.29	1.72	.01
Loam	.31	1.61	.01
	8.33		
	.71	4.51	.04
	3.67		
	1.22	6.21	.08

* Range of most annual plant roots.

(0.13 per cent) in the surface soil of Vacaville and Kenwood, with the equivalent of about 5000 pounds per acre-foot; the general average of all surface soils being 0.10 per cent, or 4000 pounds per acre-foot. This is a very good amount. In a depth of three upper feet, comprising the range of chief feeding roots of the plant, we again find the highest percentage to be in the Kenwood soil, with an average of 0.10 per cent for each foot, or about 12,000 pounds of humus-nitrogen per acre in the three feet. The Santa Rosa, Yountville, and Vacaville soils are nearly equal in their amounts of 0.08 per cent. In the entire column of twelve feet, the percentage of humus-nitrogen is greatest in the Santa Rosa alluvial (0.05 per cent), while in the Russian River alluvial and the Vaca Valley soils the percentage is 0.04 per cent. This high amount of humus-nitrogen in these soils becomes gradually available to plants only through the action of bacteria.

The soils of the valleys north of the bay region may then be considered as being well supplied in humus and humus-nitrogen, which is well distributed throughout a depth of ten or twelve feet, thus affording special inducements for deep rooting and deep feeding of plants.

The Bay Region

Alameda Plains.—The bay shore rises gently eastward to the foot of the Contra Costa Hills, a distance of about two miles. On this slope the soil is largely of an adobe clay nature. The city of Berkeley is situated on this slope, the University of California being at the foot of the hills. A column of the clay adobe was taken from the economic garden on the University grounds. Southward from Berkeley and Oakland the slope widens into a plain traversed by streams from the Coast Range bordered by wide bands of a more loamy soil, and upon it are found extensive farms. A column of the loam was taken from the land of Mrs. Sanborn, south of Niles, and another from the Meek place near Hayward.

These are excellent soils, with fair humus and humus-nitrogen. The Berkeley adobe is rich in nitrogen throughout.

TABLE 20.—HUMUS IN SOIL COLUMNS OF ALAMEDA PLAINS, ALAMEDA COUNTY

BERKELEY				HAYWARD				NILES			
Soil Clay 31.93	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 9.21	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 10.76	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
Black clay	2.13	6.67	.14	Loam	1.81	4.65	.08	Dark loam	1.10	5.36	.06
Black clay	2.07	5.97	.12	Loam	1.04	5.67	.06	Dark loam	1.00	4.20	.06
Black clay	1.84	7.33	.14	Loam	.74	6.26	.05	Dark loam	.78	5.04	.04
Black clay	1.90	4.68	.09	Loam	.80	4.73	.04	Dark loam	.56	5.01	.03
Yellow clay..	.95	7.05	.07	Loam	.92	4.58	.04	Dark loam	.44	5.74	.03
Yellow clay..	1.06	5.37	.06	Loam	.78	6.48	.05	Dark loam	.38	5.17	.02
Yellow clay..	.48	16.45	.08	Loam	.68	6.18	.04	Dark loam	.40	5.27	.02
Yellow clay..	.37	24.10	.09	Loam	.57	5.26	.03	Dark loam	.62	8.15	.05
Yellow clay..	.36	12.50	.05	Loam	.38	7.90	.03	Dark loam	.70	4.01	.03
Yellow clay..	.36	14.70	.05	Sandy.....	.32	6.58	.02	Dark loam	.68	4.54	.03
Yellow clay..	.45	9.35	.04	Dark loam	.41	6.85	.03	Dark loam	.56	4.51	.03
Yellow clay..	.49	8.16	.04	Dark clay.....	.80	1.28	.01	Dark loam	.46	6.10	.03
n of per cents	12.46				9.25				7.68		
nge per foot	1.04	10.20	.08		.77	5.53	.04		.64	5.25	.03
Upper 3 feet:*											
n of per cents	6.04				3.59				2.88		
nge per foot	2.01	6.70	.13		1.19	5.60	.06		.96	4.90	.05

* Range of most annual plant roots.

East of Contra Costa Hills.—Eastward across the Contra Costa hills several narrow valleys connect the large and fertile Livermore Valley with the bay shore on the north, and representative columns of soils were taken from three of these.

Ignacio Valley.—Along Walnut Creek there is a narrow belt of black clay-loam soil bordered by land more adobe-like in nature which extends to the low mesa and hills. The higher land on the mesa and bordering it in the valley has a stiff and black adobe clay soil about three feet in depth and underlaid by a whitish material. The column of the former was obtained from the place of Professor F. T. Bioletti, one mile north of Walnut Creek, Contra Costa County.

San Ramon Valley.—This valley is a continuation southward of Walnut Creek Valley, but wider and with more extensive black adobe soils, a column of which was obtained in the vicinity of San Ramon post office, Contra Costa County.

Livermore Valley.—The soil of the valley is a loam while that of the low hills of the west and south is reddish and gravelly. A column was taken to a depth of ten feet from the plain in the Santa Rita region, Alameda County.

TABLE 21.—HUMUS IN SOIL COLUMNS OF VALLEYS EAST OF CONTRA COSTA HILLS

	IGNACIO VALLEY CONTRA COSTA COUNTY WALNUT CREEK			SAN RAMON VALLEY CONTRA COSTA COUNTY SAN RAMON			LIVERMORE VALLEY ALAMEDA COUNTY SANTA RITA		
Ft.	Soil Clay 35.02	Humus	Humus-Nitrogen in Humus / Soil	Soil Clay 41.00	Humus	Humus-Nitrogen in Humus / Soil	Soil Clay 10.60	Humus	Humus-Nitrogen in Humus / Soil
1	Black clay	1.42	5.73 .08	Black clay	1.23	5.45 .07	Sandy loam ..	.64	8.78
2	Black clay	1.44	4.96 .07	Black clay	1.28	4.38 .06	Sandy loam ..	.83	6.02
3	Black clay	1.16	5.81 .06	Black clay	1.08	4.17 .05	Sandy loam ..	.55	5.82
4	Black clay	1.12	5.01 .06	Black clay	.84	4.29 .04	Sandy loam ..	.45	3.10
5	Black clay	1.08	5.20 .05	Gray clay.....	.81	....	Reddish loam	.34	3.23
6	Black clay	.70	7.22 .04	Gray clay.....	.75	....	Reddish loam	.37	3.78
7	Black clay	.60	6.08 .04	Gray clay.....	.29	....	Reddish loam	.43	2.57
8	Black clay	.60	6.32 .03	Gray clay.....	.20	....	Sand	.24	3.33
9	Black clay	.42	7.35 .03	Gray clay.....	.14	....	Sand	.28	2.14
10	Black clay	.52	6.75 .04	Gray clay.....	.12	....	Sand	.33	4.25
11	Black clay	.36	6.63 .02	Gray clay.....	.09	....			
12	Black clay	.26	5.40 .01	Gray clay.....	.07	....			
Sum of per cents		9.68			6.90			4.46	
Average per foot		.80	6.04 .04		.57	4.57 .05		.45	4.23
*Upper 3 feet:**									
Sum of per cents		4.02			3.59			2.02	
Average per foot		1.34	5.50 .07		1.19	4.70 .05		.67	6.31

* Range of most annual plant roots.

In these two groups of six soils, the adobe clay from Berkeley is the richest in every respect, while that from Walnut Creek is next. High percentages of humus are found to a greater depth in them than in any other of the columns. The Berkeley clay changes color below the fourth foot from black to yellow, while that from Walnut Creek remains dark throughout its twelve feet. The same change from black to gray occurs in the San Ramon adobe below the fourth foot, and each of its upper three feet contains more than 1 per cent of humus. A change from dark to red occurs in the loam soil of Santa Rita in Livermore Valley.

The humus in the Berkeley clay is surprisingly rich in nitrogen—that of the eighth foot reaching 24 per cent—but otherwise the general average of the entire column is 10.20 per cent, which is higher than has been thus far observed in any of the columns except the tule marsh of Stockton. The percentage of nitrogen in the humus of the other five columns is not especially high. For the upper three feet of the Berkeley column the average of humus-nitrogen in the soil is 0.13 per cent, or approximately 5200 pounds for each foot. This is a high amount and is probably largely due to the excellent cultivation the soil has had for years past.

The percentage of humus in the sandy loam soil taken near Santa Rita in the central part of Livermore Valley is surprisingly low in the upper part of the column, and, as a result, the surface was found dry and crusted over to such an extent that it had to be broken up before the auger could be used. Green-manure crops should be grown and turned under for several successive years in this soil, for by this the texture of the soil would be improved, more nitrogen introduced, and better crops obtained. A comparison of the soils of the two sections shows that those of the bay shore are richer in humus and in nitrogen, both in the surface foot, in the surface three feet, and in the entire column, than those east of the Contra Costa hills.

South of the Bay Region

Santa Clara Valley.—This valley, reaching from the Bay of San Francisco southward for seventy miles into San Benito County has a variety of soils. Around the bay, back from the salt marshes, there is a black clay adobe. A column of this was taken from the Morse Seed Farm near Santa Clara.

South of San José the lands are more loamy in character and are represented by a column taken from near Gilroy, by Mr. F. E. Johnson.

The valley west of San José has a soil more sandy in nature and more or less gravelly, on which is located extensive orchards. A column of this soil, seemingly representative of this land, was taken from the El Quito ranch south of Saratoga.

TABLE 22.—HUMUS IN SOIL COLUMNS OF SANTA CLARA VALLEY, SANTA CLARA COUNTY

	Morse Seed Farm, Santa Clara				El Quito				Gilroy			
	Soil Clay 58.85		Humus-Nitrogen in		Soil C 10.74		Humus-Nitrogen in		Soil Clay 23.05		Humus-Nitrogen in	
Ft.		Humus	Humus	Soil		Humus	Humus	Soil		Humus	Humus	Soil
1	Black clay	4.43	2.78	.12	Dark loam	.75	4.80	.04	Black clay	2.76	5.60	
2	Black clay	3.66	1.15	.04	Dark loam	.66	3.78	.03	Black clay	2.12	5.17	
3	Black clay	2.80	1.30	.03	Dark loam	.96	2.08	.02	Black clay	1.80	4.68	
4	Gray clay.....	.61	.....	....	Dark loam	.80	2.25	.02	Black clay	1.40	4.81	
5	Gray clay.....	.27	.....	....	Dark loam	.63	1.74	.01	Black clay	.96	5.27	
6	Gray clay.....	.20	.....	....	Dark loam	.61	2.13	.01	Black clay	.70	7.62	
7	Gray clay.....	.62	.....	....	Dark loam	.73	1.92	.01	Dark clay.....	.68	5.78	
8	Gray clay.....	.23	.....	....	Dark loam	.62	2.20	.01	Dark clay.....	.76	8.24	
9	Gray clay.....	.30	.....	....	Dark loam	.25	.....	....	Dark clay.....	.60	4.68	
10	Gray clay.....	.13	.....	....	Dark loam	.22	.....	....	Dark clay.....	.62	4.53	
11					Gravel	....	.....	....	Dark clay.....	.58	4.36	
12									Dark clay.....	.68	8.72	
Sum of per cents		13.25				6.23				13.66		
Average per foot		1.33	.....	....		.62	2.62	.02		1.14	5.21	
*Upper 3 feet:**												
Sum of per cents		10.89				2.37				6.68		
Average per foot		3.63	1.74	.06		.79	3.55	.03		2.23	5.15	

* Range of most annual plant roots.

The two clay soils from Santa Clara and Gilroy are rich in humus to depths of three and four feet respectively, and in the latter the percentage is quite large through the entire column.

In the Santa Clara column there is a sudden and great fall in percentage below the third foot, where the color also sharply changes from very black to gray. In this soil the clay percentage is very high, producing such a compact and severe texture as to prevent the downward distribution of any mass of plant roots.

The El Quito soil, if a true representative of the orchard lands of the west side of the valley, clearly lacks a sufficient supply of humus in the upper surface foot, though lower down in the column the percentage is very fair. A soil from Cupertino also had a low percentage in its surface foot; the humus, however, in both the El Quito and Santa Clara soil is surprisingly poor in nitrogen. A green-manure crop, rich in nitrogen, is clearly needed to produce conditions for high fertility. The Gilroy column has a fair amount of nitrogen.

Pajaro Valley.—The soil of the valley proper is a dark loam, while along the river are adobe clays and clay loams, the latter being largely devoted to sugar-beet culture. The valley loam is alone represented in the soil column series. It was taken from the apple-growing section on the Watsonville side of the valley. Another column of soil was taken from Watsonville Heights, one mile northwest of the town. At a depth of eight feet a mass of decomposed granite was reached. Both columns were taken by Mr. F. E. Johnson.

TABLE 23.—HUMUS IN SOIL COLUMNS FROM NEAR WATSONVILLE, SANTA CRUZ COUNTY

	PAJARO VALLEY WATSONVILLE			HEIGHTS WATSONVILLE		
Ft.	Soil Clay 9.63 Humus	Humus	Nitrogen in Humus Soil	Soil Clay 16.50	Humus	Nitrogen in Humus Soil
1	Brown loam..	1.38	6.29 .09	Dark loam ..	1.92	4.80 .09
2	Loam	.92	4.37 .05	Dark loam ..	1.46	4.60 .07
3	Loam	.94	4.77 .05	Light clay....	.50	9.00 .05
4	Loam	.74	4.54 .03	Yellow clay..	.21	6.70 .01
5	Loam	.60	4.67 .03	Yellow clay..	.11	6.40 .01
6	Loam	.60	4.67 .03	Yellow clay..	.08	7.50 .01
7	Loam	.92	4.57 .04	Gravelly	.09	8.90 .01
8	Loam	.86	3.26 .03	Gravelly	.09	4.80 .01
9	Loam	.54	5.19 .03	Hardpan	....	....
10	Loam	.62	3.61 .02			
11	Loam	.24	4.67 .01			
12	Loam	.46	4.26 .02			
Sum of per cents		8.32			4.46	
Average per foot		.74	4.61 .04		.56	6.60 .03
Upper 3 feet:[a]						
Sum of per cents		3.24			3.88	
Average per foot		1.08	5.31 .06		1.29	6.13 .07

[a] Range of most annual plant roots.

The soil of the valley is deeper than that of the Heights, but the percentages of humus in the first foot and in the upper three feet are not as great; neither is its humus so rich in nitrogen. The total amount of humus in the Pajaro Valley column is very good in its distribution downward and this, with the sandy loam nature of the soil, gives encouragement to the deep rooting of

plants in their search for food and moisture. The general average of nitrogen in the soil is good in the upper three feet where it is most needed.

Salinas Valley.—The lower or northern part of the valley for about fifty miles is from eight to twelve miles wide, but to the southward the valley is very narrow. Two classes of soil are represented in this series: a column of fifteen feet from the sandy loam lands of the west side of the Salinas River at Fort Romie near Soledad; a column of the black adobe lands around King City, Monterey County, was kindly sent by Mr. R. L. Adams, formerly of the Spreckels Beet Sugar Company.

TABLE 24.—HUMUS IN SOIL COLUMNS OF SALINAS VALLEY, MONTEREY COUNTY

	Ft. Romie				King City			
Ft.	Soil Clay 6.83	Humus	Humus-Nitrogen in Humus	Soil	Soil Clay 32.90	Humus	Humus-Nitrogen in Humus	Soil
1	Sandy	1.08	6.76	.07	Adobe clay	1.15	2.69	.03
2	Sandy	.73	8.46	.06	Adobe clay	.94	3.43	.03
3	Sandy	.50	7.30	.04	Adobe clay	.61	3.90	.02
4	Sand	.33	12.77	.04	Sandy	.25	5.04	.01
5	Loam	.78	5.76	.05	Clay loam	.52	5.39	.03
6	Loam	1.02	4.96	.05	Clay loam	.41	2.73	.01
7	Loam	.62	4.53	.03	Clay loam	.43	3.91	.02
8	Loam	.70	5.43	.04	Clay loam	.37	3.41	.01
9	Loam	.77	5.32	.04	Clay loam	.33	2.97	.01
10	Loam	.77	5.45	.04	Coarse sand	.11	6.36	.01
11	Loam	.44	5.00	.02	Coarse sand	.00	.....	....
12	Loam	.46	4.79	.02	Coarse sand	.00	.....	....
13	Loam	.36	6.94	.03				
14	Loam	.34	7.35	.03				
15	Loam	.41	6.83	.03				
	Sum of per cents in 15 feet	9.31			in 10 feet	5.12		
	Average per foot	.62	6.51	.04		.51	3.98	.02
	*Upper 8 feet:**							
	Sum of per cents	2.31				2.70		
	Average per foot	.77	7.50	.06		.90	3.34	.03

* Range of most annual plant roots.

These soils are very different in texture, that of Fort Romie being of a sandy nature throughout eighteen feet or more, while that from King City is a stiff clay for a depth of three feet, changing to sand and then a clay loam. The effect of the presence of the sand is shown in the sudden diminution of humus in the fourth foot, and the same change is noted in the tenth foot.

The deep rooting of plants is more marked in the Fort Romie soil by the higher percentages of humus in the lower half of the column. The humus and the soil are each also richer in nitrogen than that of the King City clay, which clearly would be greatly benefited in texture and richness by systematic green-manuring with legumes.

The column of soil from Fort Romie was continued to water at fifteen feet and humus found in fair amount in the last foot.

Arroyo Grande Valley.—The soil of this narrow but important valley is of a dark and heavy clay loam nature to the depth of

TABLE 25.—HUMUS IN SOIL COLUMNS OF ARROYO GRANDE VALLEY, SAN LUIS OBISPO COUNTY

	ARROYO GRANDE			ROUTZAHN SEED FARM		
Ft.	Soil Clay 17.99 Humus	Humus-Nitrogen in Humus	Soil	Soil Clay 28.80 Humus	Humus-Nitrogen in Humus	Soil
1	Black loam.... 2.50	6.46	.16	Black clay 3.78	4.31	.16
2	Black loam.... 2.15	4.67	.10	Dark loam 1.50	4.96	.07
3	Black loam.... 1.83	5.37	.10	Dark loam 1.13	5.95	.07
4	Black loam.... 1.54	5.65	.09	Dark loam 1.52	3.88	.06
5	Dark loam 1.04	5.31	.09	Dark loam 1.34	4.82	.07
6	Dark loam 1.56	4.68	.07	Light clay..... .64	5.27	.03
7	Dark loam 1.36	6.30	.09	Light clay..... 1.04	5.67	.06
8	Dark loam .... .88	8.30	.07	Light clay..... .70	7.22	.05
9	Light loam .... .62	6.36	.04	Light clay..... .84	6.02	.05
10	Dark clay..... .82	5.48	.05	Light clay..... .96	5.56	.05
11	Dark clay..... .88	5.11	.05	Light clay..... .76	5.91	.05
12	Dark clay..... .86	5.22	.05	Dark clay..... 1.20	5.75	.07
Sum of per cents	16.64			15.46		
Average per foot	1.39	5.74	.08	1.29	5.44	.07
*Upper 3 feet:**						
Sum of per cents	6.48			6.46		
Average per foot	2.16	5.50	.12	2.15	5.07	.10

* Range of most annual plant roots.

twelve feet and more. Two columns were obtained by Mr. F. E. Johnson, one near the town of Arroyo Grande, the other from the farm of the Routzahn Seed Company, a few miles to the westward, the only apparent difference being a darker color in the surface foot of the seed-farm soil.

The soil from the Routzahn seed-farm in the Arroyo Grande Valley is certainly remarkably rich in humus for an arid soil; for not only does each foot of the upper five feet and also the seventh contain more than 1 per cent, but the twelfth foot has 1.20 per cent and the tenth nearly 1 per cent. The soil from near the town of Arroyo Grande is even richer than that of the seed-farm, for it contains not only more than 1.50 per cent of humus in each of the upper seven feet, but each of the lower five feet lacks but little of having 1 per cent.

The percentages of humus-nitrogen in these soils are also very high, especially in the upper few feet of each column, that of

TABLE 26.—HUMUS IN SOIL COLUMNS OF SANTA MARIA AND LOMPOC VALLEYS, SANTA BARBARA COUNTY

	SANTA MARIA VALLEY SANTA BARBARA COUNTY WEST OF SANTA MARIA			LOMPOC VALLEY SANTA BARBARA COUNTY BURPEE SEED-FARM		
Ft.	Soil Clay 10.25	Humus	Humus-Nitrogen in Humus Soil	Soil Clay 33.40	Humus	Humus-Nitrogen in Humus Soil
1	Dark loam	1.44	9.57 .11	Dark clay	2.50	5.28 .13
2	Dark loam	1.11	4.81 .05	Dark clay	1.56	4.62 .07
3	Dark loam	.84	5.52 .05	Dark clay	1.51	4.90 .07
4	Light loam	.36	9.72 .03	Dark clay	1.93	6.12 .12
5	Light loam	.46	7.76 .04	Dark clay	1.07	5.32 .06
6	Light loam	.32	8.97 .03	Dark clay	1.18	7.28 .09
7	Light loam	.24	9.36 .02	Dark clay	1.33	5.94 .08
8	Gray loam	.21	11.36 .02	Dark clay	.80	6.13 .05
9	Gray loam	.21	12.03 .03	Dark clay	.43	6.27 .03
10	Gray loam	.23	9.77 .02	Dark clay	.21	8.58 .02
11	Gray loam	.09	18.72 .02	Dark clay	.24	8.75 .02
12	Gray loam	.16	17.15 .03	Dark clay	.27	8.53 .02
Sum of per cents		5.57			13.03	
Average per foot		.46	10.40 .04		1.09	6.50 .05
*Upper 3 feet:**						
Sum of per cents		3.39			5.57	
Average per foot		1.13	6.67 .07		1.86	4.93 .09

* Range of most annual plant roots.

the surface foot being 0.16 per cent, or approximately 6400 pounds per acre. This extreme richness in humus and nitrogen, as well as in potash and phosphoric acid, is responsible for the high productiveness and the national reputation the valley enjoys as a vegetable-seed producing region.

Santa Maria Valley.—The soil is chiefly a sandy loam of a brownish color and very deep. A column was taken by Mr. F. E. Johnson near the sugar-beet fields five miles west of the town of Santa Maria.

Lompoc Valley.—Three chief classes of soils occupy the valley—adobe near the hills, sandy alluvium near Santa Inez River, and an intermediate type of clay loam between them. The Burpee seed-farm is situated on the clay loam lands, and a column of soil was taken there to a depth of twelve feet, at which point water was reached.

Santa Maria Valley soil has a fair amount of humus in the upper three feet and low percentages through the rest of the column, and this humus has high percentages of nitrogen. The smaller amounts in the second and third foot may be due to withdrawal by plant roots. The general average of organic nitrogen in the upper three feet of soil is good, but for the entire column the percentage is low, because of the low amount of humus.

In strong contrast to the sandy loam soil of Santa Maria Valley is the heavier clay of the Lompoc Valley through which flows Santa Inez River. The upper seven feet of the Burpee soil each contains more than 1 per cent of humus, and this, though not especially rich in nitrogen, gives to the soil itself fairly high percentages, the average in the upper three feet being 0.09 per cent, or about 10,000 pounds per acre.

Summary of Results in Coast Range Region

The soils of the valleys of the Coast Range are remarkably high in their humus content when compared with the other soils of the arid region. The general average of the state is 1.25 per cent in the surface soil, while that for these coast valleys is 1.94 per cent. But especially does this difference appear when we note the many soils in which more than 1 per cent of humus is found

columns there is a decrease downward, indicating that the humification was of plant roots rather than of vegetable matter deposited from overflow as the land was being built up.

A comparison of the results of the examination of the first foot gives an average of 2.08 per cent of humus north of the bay, 1.82 per cent for the bay region, and 1.93 for the region south, while for the three upper feet the averages are 1.55, 1.59, and 1.45 per cent respectively. This shows quite a close agreement in the soils of the valleys of the three divisions.

A glance over the tables brings out the fact that the Santa Clara soil has a higher amount of humus (4.43 per cent) in the first foot than any soil of the state, except the marsh soils, and that nine of the twenty-five columns of the Coast Range have more than 2 per cent in the surface foot, while in all others but two there is more than 1 per cent.

The portion of the soil column lying below the first foot is richer in humus than that of other agricultural regions. There is more than 1 per cent in each of the four upper feet of ten of the twenty-four columns of the Coast Range; in the columns from Santa Rosa, Russian River, Walnut Creek, and Berkeley this percentage extends through five feet, while in the soil from Lompoc and Arroyo Grande it reaches through seven feet.

The humus of the Santa Maria soil is richest in nitrogen, 9.57 per cent, that of Livermore Valley being next with 8.78. The surface soils whose humus is poorest in nitrogen according to the analyses are King City and Santa Clara adobes. The general average for the twenty-four columns is 5.36 per cent.

The percentage of nitrogen in the surface soil is highest in the soils from Arroyo Grande, viz., 0.16 per cent, or approximately 6400 pounds per acre. Gilroy has 0.15 per cent, Berkeley 0.14 per cent, Lompoc, Vacaville, and Kenwood 0.13 per cent each, and Santa Clara, El Verano, Santa Maria, and Yountville each has more than 0.10 per cent.

Humus in the Upper Three Feet.—The percentage of humus in the upper three feet has a summation of 10.89 for the Santa Clara, a little more than 6 per cent for Gilroy, Berkeley, and the two Arroyo Grande columns, and 5.57 per cent for Lompoc, but all others are below this.

The humus of the upper three feet of the Fort Romie soil is richest in nitrogen, 7.50 per cent, while that of the Santa Clara adobe has only an average of 1.74 per cent. The general average of all of this portion of the columns is 5.00 per cent, although fourteen of the twenty-four have a higher percentage.

The humus-nitrogen in this portion of the column varies from 0.13 per cent in the Berkeley adobe, 0.11 per cent in the soils from Gilroy and Arroyo Grande, to more than 0.05 per cent in all others except four.

Humus in the Entire Column.—Nine of the twenty-four columns have greater amounts of humus in their depths of ten or twelve feet than has been found in any of the columns representing other parts of the state. The two columns from the Arroyo Grande, with sums of 16.74 per cent and 15.56 per cent, have the highest amounts and are followed in the order of highest by Gilroy, Santa Clara, and Lompoc, each with more than 13.00 per cent, and Berkeley, Russian River Valley, Yountville, Santa Rosa, and El Verano, each with more than 11.00 per cent.

The humus of the entire soil columns of the Coast Range valleys is about as rich in organic nitrogen as that of other soils of the state, the highest average percentage being in the Santa Maria soil and the Berkeley adobe, 10.40 and 10.21 per cent respectively; the Kenwood and Lompos soils are the next in amount, with 7.79 and 6.50 per cent respectively. The Walnut Creek column has an average of 6.04 per cent, but all other averages are below 6 per cent for the entire column. The organic nitrogen of the soil itself varies from 0.08 per cent in the Arroyo Graude, Berkeley, and Kenwood columns, 0.07 per cent in the Arroyo Grande seed-farm to 0.05 per cent in Santa Rosa, Walnut Creek, San Ramon, and Lompoc; but all others have less.

SOIL COLUMNS OF SOUTHERN CALIFORNIA

The region known as Southern California embraces that part of the state lying south of the Sierra Madre and Santa Ynez mountains and includes a number of large and fertile valleys and plains.

Saticoy Plain.—The long and broad slope in Ventura County, reaching from the mountains southward to the sea-shore and noted for its lima bean culture, is represented by two soil columns, one taken by Mr. J. B. Neff from near Mound Schoolhouse, a few miles east of Ventura, and the other from the orange grove of Mr. N. B. Blanchard, at Santa Paula.

TABLE 27.—HUMUS IN SOIL COLUMNS OF SATICOY PLAINS, VENTURA COUNTY

	Mound Schoolhouse			Santa Paula			
Ft.	Soil Clay 14.18	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 15.02	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1	Loam	1.23	5.14	.06	Dark loam	1.23	5.61	.07
2	Loam	1.36	4.96	.07	Dark loam	.84	6.90	.06
3	Loam	.52	5.67	.03	Dark loam	.53	6.60	.04
4	Loam	.57	6.84	.04	Light loam	.45	6.00	.03
5	Loam	.54	5.46	.03	Light loam	.23	11.30	.03
6	Loam	.48	5.27	.03	Light loam	.21	20.47	.04
7	Loam	.54	4.68	.03	Dark loam	.56	9.81	.06
8	Loam	.45	4.99	.02	Dark loam	.59	1.69	.01
9	Loam	.36	4.68	.02	Dark loam	.52	10.00	.05
10	Loam	.51	4.13	.02	Dark loam	.38	9.74	.04
11	Loam	.60	3.98	.02	Dark loam	.33	7.27	.02
12	Loam	.52	4.32	.02	Fine gravel	.24	.....	....
	Sum of per cents	7.68				6.11		
	Average per foot	.64	5.01	.03		.51	8.67	.04
	*Upper 3 feet:**							
	Sum of per cents	3.11				2.60		
	Average per foot	1.04	5.26	.05		.87	6.37	.06

* Range of most annual plant roots.

The soil from Mound is the better of these two from Saticoy Plain, because of the higher percentage of humus in the column below the first foot; its second foot is richer than the first, and the entire amount is greater than in the Santa Paula. But its humus is poorer in nitrogen (5.01 per cent) than that of Santa Paula (8.67 per cent), and the soil itself is not so well supplied. The upper three feet of each column has a fair amount of soil nitrogen.

It would naturally be supposed that the growing of beans for so many years and leaving the roots and stubble in the ground

would have greatly enriched the Mound soil with nitrogen from the leguminous crop, but it seems to have produced but little if any advantage over the orange orchard land; in fact, the humus of the latter is far richer in nitrogen, perhaps because of the use of fertilizers.

Santa Clara River Delta.—This comprises a broad region of dark alluvial land and contains more or less alkali salts in places. Water is usually found at a depth of eight or ten feet below the surface. The delta is noted for its sugar-beet culture. A column was taken near Springville by Mr. J. B. Neff to a depth of eight feet, at which water was reached.

Pleasant Valley Hill Slope.—This column was taken from the sandy slope of the hills north of the Southern Pacific Railroad station of Camarillo.

TABLE 28.—HUMUS IN SOIL COLUMNS OF HILLSIDE AND DELTA OF SANTA CLARA RIVER, VENTURA COUNTY

	Pleasant Valley Hillside, Camarillo			River Delta Springville			
Ft.	Soil Clay 7.01	Humus	Humus-Nitrogen in Humus	Soil	Soil Clay 7.72	Humus	Humus-Nitrogen in Humus	Soil
1	Sandy	.84	6.19	.05	Dark loam	.96	7.31	.07
2	Sandy	.75	4.93	.04	Dark loam	.58	6.29	.04
3	Sandy	.37	.....	....	Dark loam	.42	4.68	.02
4	Sandy	.33	.....	....	Sandy	.20	8.44	.02
5	Sandy	.33	.....	....	Sandy	.14	5.14	.01
6	Sandy	.20	.....	....	Sandy	.18	4.69	.01
7	Sandy	.18	.....	....	Silty	.22	5.11	.01
8	Sandy	.12	.....	....	Sand	.14	5.14	.01
9	Sandy	.17	.....	....				
10	Sandy	.13	.....	....				
11	Sandy	.13	.....	....				
12	Sandy	.11	.....	....				
	Sum of per cents	3.66				2.84		
	Average per foot	.30	.....	....		.34	5.70	.02
	*Upper 3 feet:**							
	Sum of per cents	1.96				1.96		
	Average per foot	.65	.....	....		.65	6.20	.04

* Range of most annual plant roots.

The soil from Springville in the delta of Santa Clara River is not so rich in humus as its dark color would lead one to suppose, and the entire column of eight feet is quite light though the land is highly productive. A soil from near Oxnard previously examined was found to contain as much as 1.60 per cent of humus, and it would seem that the great body of land farther out in the valley is richer than that near the hills. An interesting example of the penetration of plant roots and their humification in a sandy soil is seen in the column from the hillside slope north of Camarillo station in Pleasant Valley. It is interesting to note that this soil in the three upper feet has the same percentage as that of the Springville column, although so different in color and texture.

San Fernando Valley.—The valley of San Fernando lies north of Los Angeles and includes about two hundred square miles. Much of the valley on the east is covered by debris of cobblestones, gravel, and sand washed from the cañons on the northeast,

TABLE 29.—HUMUS IN SOIL COLUMNS OF SAN FERNANDO VALLEY, LOS ANGELES COUNTY

	SAN FERNANDO				MISSION SAN FERNANDO			
Ft.	Soil Clay 11.15	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 8.56	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1	Loam	1.08	4.68	.05	Loam	.72	5.46	.04
2	Loam	.70	4.81	.03	Loam	.54	6.24	.03
3	Loam	.70	4.61	.03	Loam	.50	5.05	.03
4	Loam	.54	4.16	.02	Loam	.44	6.38	.03
5	Loam	.52	3.51	.02	Loam	.36	5.46	.02
6	Loam	.46	3.66	.02	Loam	.34	5.37	.02
7	Loam	.40	5.62	.02	Loam	.34	5.37	.02
8	Loam	.20	4.21	.01	Loam	.36	4.68	.02
9	Loam	.24	3.51	.01	Loam	.42	4.35	.02
10	Loam	.28	3.01	.01	Loam	.34	5.78	.02
11	Loam	.20	4.21	.01	Loam	.30	5.62	.02
12	Loam	.22	3.83	.01	Loam	.26	5.40	.01
Sum of per cents		5.54				4.92		
Average per foot		.46	4.23	.02		.41	5.43	.02
*Upper 3 feet:**								
Sum of per cents		2.48				1.76		
Average per foot		.83	4.70	.04		.59	5.58	.03

* Range of most annual plant roots.

but the rest of the valley has sandy and sandy loam soils, with some heavier clays on the south.

Two columns were obtained by Mr. F. E. Johnson—one from the sandy lands about one-half mile north of Fernando and representing the "granitic wash land" at the foot of the hills; the other from lowland near the old Mission two miles west of Fernando.

The two soils from the San Fernando Valley are quite different in their percentages of clay as well as in amounts of humus in the first foot, in the upper three feet, and in the entire column, the advantage being with the soil from near San Fernando. The Mission soil is more sandy because of the wash from the hills. While the humus of the Mission column is the richer in nitrogen, the two are equal so far as the soil is concerned and are much below the requirements for fertility.

The soil from San Fernando probably is similar in character to that of the large olive orchard at Sylmar, a few miles north near the foot of the hills.

TABLE 30.—HUMUS IN SOIL COLUMNS OF SAN GABRIEL VALLEY, LOS ANGELES COUNTY

	Monrovia				Covina			
Ft.	Soil Clay 7.61	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 6.84	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1	Sandy loam..	.94	3.82	.04	Sandy loam..	.58	5.31	.03
2	Sandy loam..	.58	3.77	.02	Sandy loam..	.48	4.08	.02
3	Sandy loam..	.56	3.75	.02	Sandy loam..	.46	4.26	.02
4	Sandy loam..	.62	3.54	.02	Sandy loam..	.32	5.25	.02
5	Sandy loam..	.64	3.59	.02	Sandy loam..	.30	5.60	.02
6	Sandy loam..	.48	3.13	.02	Sandy loam..	.26	5.38	.01
7	Sandy loam..	.34	3.24	.01	Sandy loam..	.24	5.83	.01
8	Sandy loam..	.26	3.07	.01	Sandy	.18	4.51	.01
9	Sandy loam..	.28	2.86	.01	Sandy	.16	4.38	.01
10	Sandy loam..	.30	2.67	.01	Sandy	.18	3.89	.01
11	Sandy loam..	.28	2.50	.01	Gravelly	.18	3.89	.01
12	Sandy loam..	.28	2.86	.01	Coarse gravel	....	.....	....
Sum of per cents		5.56				3.34		
Average per foot		.46	3.24	.02		.28	4.75	.02
*Upper 3 feet:**								
Sum of per cents		2.08				1.51		
Average per foot		.69	3.78	.03		.50	4.55	.02

* Range of most annual plant roots.

San Gabriel Valley.—This valley lies east of Los Angeles and reaches from the mountains southward to the alluvial plains. It is watered by the San Gabriel River and bordered on the east by the Puente Hills, and the San Antonio debris cone. Its soil is a sandy loam. A column of soil was taken by Mr. F. E. Johnson from the neighborhood of Covina and "represents an average of all of the different soil types." Another column was taken by Mr. Johnson from near Monrovia and represents the heavier type of soil, the greater part of which is sandy and gravelly wash from the hills.

These soils are quite deficient in the necessary amount of humus to keep them in good physical condition and to furnish adequate nitrogen for the plants.

Attention of orchard growers should especially be given to the yearly growing and turning under of the best leguminous crop available—a crop giving large yields of succulent, easily decomposed stems and leaves and containing high percentages of nitrogen. Until a fair supply of humus in the three upper feet are secured by this method, it seems necessary to apply nitrogen fertilizers to the trees with sufficient irrigation water to carry them down to the feeding roots at a depth of several feet below the surface.

San Bernardino Valley.—The eastern portion of the valley of Southern California known as the San Bernardino Valley is separated from the western by a range of low hills and by the debris cone of the San Antonio Creek, which issues from its valley just above Pomona and supplies most of the water to Chino Creek which empties into the Santa Ana River. In the past from time to time, a portion of the San Antonio flow has been diverted into the San Gabriel.

The valley covers a large area and comprises a large variety of soil types, a few of which are represented by soil columns. The valley slopes toward the south to the Rincon Basin and Santa Ana River, and is bordered by a rim of mesa land on the north, east, and south.

The Valley Plains.—The soils in the central part of the valley are chiefly of a sandy nature, of excellent depth and good fertility. The lowlands are usually highly charged with alkali that

has been brought in by drainage from the higher valley. Several types of soil from the plains are represented in the columns.

Sandy loam soils of the central part of the valley are shown in a column taken by Mr. J. W. Mills from the former University of California Experiment Station tract three miles southwest of Ontario.

Highly sandy soils, apparently accumulated by wind storms blowing in from the mountain passes on the north, lie in the central part of the valley and are extensively planted in grape vines, the roots of which penetrate downward for very many feet. A column of this type of soil was secured at Guasti from the land of the Italian Vineyard Company.

Alluvial plains of the Santa Ana River, known as the Victoria Tract, a few miles east of San Bernardino.

The soils of the valley plain are all quite sandy and contain but small amounts of humus and of nitrogen. The tendency to crust over and to form a sandy hardpan or plowsole near the surface is quite usual with these soils. A succession of good

TABLE 31.—HUMUS IN SOIL COLUMNS OF VALLEY LANDS, SAN BERNARDINO COUNTY

SOUTHWEST OF ONTARIO				VICTORIA TRACT				GUASTI			
Soil Clay 7.60	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 3.38	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 3.81	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
Sandy	.36	4.68	.02	Loam	.69	4.92	.03	Sandy	.25	3.36	.01
Sandy	.23	5.74	.01	Loam	1.02	4.62	.05	Sandy	.18	4.42	.01
Sandy	.19	3.70	.01	Loam	.62	2.26	.01	Sandy	.14	4.00	.01
Sandy	.13	5.40	.01	Loam	.37	3.80	.01	Sandy	.12	.....	....
Sand	.10	4.21	.01	Loam	.24	2.92	.01	Sandy	.09	.....	....
Sand	.08	3.51	.01	Loam	.18	2.22	.01	Sandy	.08	.....	....
Sand	.09	3.12	.01	Sand	.16	1.26	....	Sandy	.07	.....	....
Sand	.06	.....	....	Sand	tr.	.....	....	Sandy	.11	.....	....
Coarse sand	....	.....	....	Coarse sand	....	.....	....	Sandy	.08	.....	....
Coarse sand	....	.....	....	Coarse sand	....	.....	....	Sandy	.07	.....	....
Coarse sand	....	.....	....	Coarse sand	....	.....	....	Sandy	.07	.....	....
Coarse sand	....	.....	....	Coarse sand	....	.....	....	Sandy	.07	.....	....
Total per cents	1.23				3.28				1.33		
Average per foot	.10	4.34	.01		.27	3.00	.01		.11	.....	....
Upper 3 feet:*											
Total per cents	.77				2.33				.57		
Average per foot	.26	4.70	.01		.78	3.93	.03		.19	3.92	.01

* Range of most annual plant roots.

green-manure crops grown, turned under deeply, and allowed to humify properly would add much to the value and fertility of these lands.

Low Lands.—Near the border of Chino Creek there are low-lying lands forming a wide border of "moist lands" which do not need irrigation. Ten acres of this near Chino formerly formed a part of the Experiment Station. A column from this was taken by Mr. F. E. Johnson. Another column was taken near Pomona from a marsh spot known as a "cienega." This is a "limited area showing growth of water-loving plants, appearing sporadically in otherwise arid surroundings—usually hillsides or valley margins—and occasionally giving rise to flowing springs."—(Rept. Calif. Expt. Sta., 1892-4, p. 185.)

TABLE 32.—HUMUS IN SOIL COLUMNS OF LOWLANDS, SAN BERNARDINO VALLEY

SAN BERNARDINO COUNTY — CHINO				LOS ANGELES COUNTY — POMONA CIENEGA			
Soil Clay 13.44 Ft.	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Marsh	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1 Dark silt	2.31	4.86	.11	Black loam....	6.26	4.06	.25
2 Dark silt	1.41	4.28	.08	Black loam....	3.12	3.50	.11
3 Dark silt	.84	5.52	.05	Black loam....	1.84	3.12	.05
4 Dark silt	1.05	4.01	.04	Sandy	.72	18.30	.13
5 Blue clay.....	.72	6.14	.04	Sand	.12	3.88	.01
6 Blue clay.....	.82	5.65	.05	Sand	.66	2.12	.01
7 Blue clay.....	.78	5.38	.04	Coarse sand..	.15	2.00	.01
8				Blue sand	.63	1.59	.01
9				Blue sand	.61	1.31	.01
10				Blue sand	.55	1.82	.01
11				Blue sand	.30	2.32	.01
12				Blue sand	.57	1.41	.01
Sum of per cents	7.93				15.33		
Average per foot	1.13	5.12	.06		1.28	3.66	.05
*Upper 3 feet:**							
Sum of per cents	4.56				11.02		
Average per foot	1.52	4.90	.07		3.67	3.56	.14

* Range of most annual plant roots.

In each of these lowland soils the humus content is excellent though not especially rich in nitrogen. The large amount of the former, however, makes up for any low percentage of nitrogen

and gives to the soil an adequate amount, especially in the upper few feet.

The Chino soil was found on previous examination to hold quite high amounts of alkali salts, among which was nitrates of soda and magnesia (Rept. Calif. Expt. Sta., 1894–5, p. 75).

Mesa Lands.—The mesa lands that border the valley are largely of a reddish loam type, interspersed on the north side by deposits of sand and gravel from the hillsides.

The red mesa extends eastward up the San Gorgonio Pass to its summit at Banning, where it forms quite a high plateau above Timoteo Cañon.

A column of the sandy mesa of the north side was taken in the western part of Highlands to a depth of twelve feet, in which the sandy soil continued to the bottom.

A column representing the red clay mesa was taken near Redlands by Mr. F. E. Johnson. The upper five feet was of a reddish sandy loam nature, below which it changes to a sandy clay and finally to a gritty material.

TABLE 33.—HUMUS IN SOIL COLUMNS OF NORTH-SIDE MESA OF SAN BERNARDINO VALLEY

HIGHLANDS				REDLANDS			
Ft. Soil Clay 4.66	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 10.33	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1 Sandy	.72	6.25	.05	Red loam	.43	5.88	.03
2 Sandy	.46	9.78	.05	Red loam	.33	5.09	.02
3 Sandy	.43	7.90	.03	Red loam	.27	5.20	.01
4 Sandy	.37	8.10	.03	Red loam	.22	5.11	.01
5 Sandy	.32	7.18	.02	Red loam	.20	5.75	.01
6 Sandy	.28	6.07	.02	Sandy clay	.10	8.42	.01
7 Sandy	.27	6.29	.02	Sandy clay	.10	8.42	.01
8 Sandy	.25	6.80	.02	Sandy clay	.10	8.42	.01
9 Sandy	.25	7.60	.02	Gritty	.07	7.00	.01
10 Sandy	.22	7.72	.02	Gritty	.08	7.00	.01
11 Sandy	.14	10.00	.02	Gritty	.06	.....	....
12 Sandy	.11	17.27	.02	Gritty	.07	.....	....
Sum of per cents	3.82				2.03		
Average per foot	.32	8.41	.03		.17	6.63	.01
*Upper 3 feet:**							
Sum of per cents	1.61				1.03		
Average per foot	.54	8.00	.04		.34	5.39	.02

* Range of most annual plant roots.

The percentage of humus in each of the above soils is very low, especially in that of the red loam of the Redlands mesa. The percentages decrease steadily into the lower portions of each column.

The Highlands sandy soil is the richer of the two, both in humus and nitrogen, and in the entire column except the upper three feet is fairly supplied with each of these.

The Redlands soil, because of its heavier clay nature, would be more benefited by green-manuring than would that of Highlands.

South-side Mesa.—On the south side of the valley the mesa rises from near the border of Santa Ana River and extends to the hills at elevations much above the plains. The soil is very generally a reddish clay loam, more or less gravelly, and overlies granitic debris at depths of many feet.

TABLE 34.—HUMUS IN SOIL COLUMNS OF SOUTH-SIDE MESA OF SAN BERNARDINO VALLEY

	CORONA			RIVERSIDE		
Ft.	Soil Clay 12.87	Humus	Humus-Nitrogen in Humus Soil	Soil Clay 11.78	Humus	Humus-Nitrogen in Humus Soil
1	Red loam.....	.71	7.91 .06	Red loam.....	.63	4.00 .03
2	Red loam.....	.41	6.85 .03	Red loam.....	.30	6.08 .02
3	Red loam.....	.42	4.68 .02	Red losm.....	.20	6.32 .01
4	Red loam.....	.25	4.49 .01	Red loam.....	.11	5.11 01
5	Gravelly.....	.15	5.62 .01	Red loam.....	.11	5.11 .01
6	Gravelly.....	.14	6.02 .01	Red loam.....	.12	5.85 .01
7	Gravelly.....	.17	3.30 .01	Red loam.....	.11	5.11 .01
8	Gravelly.....	.26	3.24 .01	Red loam.....	.10	4.00 .01
9	Gravelly.....	.21	4.01 .01	Red loam.....	tr.	....
10	Gravelly.....	.17	3.30 .01	Red loam.....	....	....
11	Gravelly.....	.18	3.12 .01	Red loam.....	....	....
12	Gravelly.....	.30	3.74 .01	Red loam.....	....	....
	Sum of per cents	3.37			1.68	
	Average per foot	.28	4.70 .02		.14	5.19 .01
	*Upper 3 feet:**					
	Sum of per cents	1.54			1.13	
	Average per foot	.51	6.48 .04		.09	5.47 .02

* Range of most annual plant roots.

A column from Riverside was taken from Arlington Heights orchard lands on the south, with the assistance of Mr. J. H. Reed, and we were able to reach a depth of eighteen feet with comparative ease.

Another mesa soil column was taken by Mr. F. E. Johnson from nearly one mile south of the town of Corona, and is a good representative of the orchard land of that vicinity. A depth of twelve feet was reached with difficulty because of the presence of much gravel.

The red mesa land on the south side of the valley also contains very low percentages of humus and of nitrogen. This is especially true of the Riverside soil, more than one-half of whose supply is in the upper two feet. Its nitrogen is also very low. The Corona soil is somewhat richer in nitrogen, but in both soils and doubtless on the rest of the mesa, the need of good green-manure crops for the production of humus is very apparent.

Los Angeles Alluvial Plain.—The three rivers, Los Angeles, San Gabriel, and Santa Ana, have each brought down from the San Bernardino Mountains large quantities of silt, sand and clay and formed a large body or region of alluvial lands known as the Los Angeles alluvial plains. Each river preserves its own course through these plains and has built up its own alluvial plain with its own material independently of the others. We thus find that the soils of the San Gabriel are of a more sandy nature than those of the Santa Ana, probably because of the more rapid velocity of the river current over a shorter distance; the Santa Ana leaves the mountains east of San Bernardino and flows by a circuitous route along the southern side of the valley and thus seems to have left much of its coarse material behind and deposited chiefly clays and silts in the alluvial plain.

The San Gabriel Plain is represented by three columns. One was taken from the place of Dr. S. S. Twombly, south of Fullerton, to a depth of ten feet; another from the place of Mr. J. B. Neff, near Anaheim; while the third column was taken a mile south of Compton.

The land of that plain belonging to the San Gabriel and especially between this and the Santa Ana River is greatly varied in character, as is indicated by these three columns. In some

TABLE 35.—HUMUS IN SOIL COLUMNS OF SAN GABRIEL RIVER ALLUVIAL PLAIN, ORANGE COUNTY

	FULLERTON				ANAHEIM				COMPTON		
Ft.	Soil Clay 7.94	Humus	Humus-Nitrogen in Humus	Soil	Soil Clay 5.78	Humus	Humus-Nitrogen in Humus	Soil	Soil Clay 7.45	Humus	Humus-Nitrogen in Humus
1	Loam	.51	10.89	.06	Sandy	.88	8.00	.07	Dark loam	1.50	6.[illegible]
2	Loam	.64	7.82	.05	Sandy	.83	6.46	.05	Dark loam	.91	9.[illegible]
3	Loam	.25	18.40	.05	Sandy	.68	6.91	.05	Dark loam	.51	6[illegible]
4	Loam	.22	15.45	.03	Sandy	.49	8.00	.04	Light loam	.60	7.[illegible]
5	Loam	.22	20.45	.05	Sandy	.41	6.09	.03	Dark loam	.49	5.[illegible]
6	Loam	.26	10.77	.03	Sandy	.33	6.06	.02	Light loam	.53	7.[illegible]
7	Loam	.33	15.15	.05	Sandy	.33	4.58	.02	Light loam	.64	5.[illegible]
8	Loam	.29	19.31	.06	Sandy	.25	4.40	.01	Light loam	.52	7.[illegible]
9	Loam	.29	12.41	.04	Sandy	.22	.38	.01	Fine sand	.38	12.[illegible]
10	Loam	.29	19.31	.06	Sandy	.24	.28	.01	Fine sand	.42	5.[illegible]
11									Dark loam	.49	4.[illegible]
12									Dark loam	.32	3.[illegible]
Sum of per cents		3.30				4.66				7.31	
Average per foot		.33	15.00	.05		.46	5.12	.03		.61	6
*Upper 3 feet:**											
Sum of per cents		1.40				2.39				2.92	
Average per foot		.47	12.40	.05		.79	7.12	.06		.97	7

* Range of most annual plant roots.

localities, as around Compton, the soil is of a dark sandy loam nature, quite micaceous and contains more humus than elsewhere. The Compton column is fairly well supplied with humus and nitrogen throughout the depth of twelve feet, and conditions seem to be especially favorable for deep rooting of plants. In other localities there are heavy sandy deposits from old river overflows, the soil of which while quite fertile needs humus to give it a stronger texture.

The Anaheim column was taken from a walnut orchard whose owner had practiced a system of green-manuring for a number of years with good results. While the percentage of humus is still rather low, yet it contains much nitrogen in the upper portion of the column. The sandy loam soils along the border of this alluvial plain near Fullerton, represented by a column a short distance south of town, are surprisingly low in their humus content, but the humus is remarkably rich in nitrogen, not in

isolated levels as often occurs in other soils, but throughout the entire column, the general average being 0.15 per cent, or approximately 6000 pounds of nitrogen per acre-foot through the entire depth. No other column from the entire collection has a similar record. Bacterial activity to render this humus-nitrogen available to plants should make unnecessary the use of nitrogen fertilizers.

The Santa Ana Alluvial Plain is represented by two columns taken by Mr. F. E. Johnson. One of these from two miles south of Santa Ana, represents a considerable area of heavy black adobe; the other, from Irvine Station six miles southeast of Santa Ana, represents a lighter clay loam soil. Both of these columns are from the south side of Santa Ana River.

TABLE 36.—HUMUS IN SOIL COLUMNS OF SANTA ANA RIVER ALLUVIAL PLAIN, ORANGE COUNTY

	SANTA ANA				IRVINE			
Ft.	Soil Clay 25.01	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 18.31	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1	Black clay	2.42	3.71	.09	Clay loam	.70	5.86	.04
2	Black clay	1.44	3.51	.05	Clay loam	.50	3.40	.04
3	Black clay	1.02	4.80	.05	Clay loam	.44	4.09	.02
4	Light clay	.83	5.90	.05	Clay loam	.38	3.42	.01
5	Light clay	.76	2.22	.02	Clay loam	.34	1.76	.01
6	Light clay	.46	2.75	.01	Sand	.22	1.82	.01
7	Light clay	.31	2.72	.01	Sand	.19	.63	.01
8	Light clay	.22	2.55	.01	Sand	.20	1.50	.01
9	Sandy	.12	2.34	tr.				
10	Sandy	.14	3.01	....				
11	Sandy	.14	3.01	....				
12	Sandy	.20	4.18	....				
Sum of per centa		8.06				2.97		
Average per foot		.67	3.40	.03		.23	3.43	.02
*Upper 3 feet:**								
Sum of per centa		4.88				1.64		
Average per foot		1.63	4.00	.06		.55	6.12	.03

* Range of most annual plant roots.

The adobe clay of Santa Ana contains a fair amount of humus, but the humus is very poor in nitrogen throughout the entire column. In spite of the latter fact, however, the per-

centage of nitrogen in the soil is fair, especially in the first foot. The loam soil from Irvine is not so well supplied with humus and nitrogen as could be desired.

Interior Valleys

The immediate coast line is bordered by a wide mesa which extends south to the state line, interrupted by the characteristic deep and narrow valleys or occasional streams. The valley of the San Diego River is wide and affords much land for culture purposes. The mesa reaches eastward in width to the foot of the higher rolling hills, which rise still higher into the San Jacinto Mountains. Among these hills lie numerous valleys, small and large, whose soils are rich and productive.

Fallbrook Mesa.—The hills are for the most part somewhat rolling and capable of cultivation whenever the soil is of sufficient depth and extent. Fallbrook affords an example of these cultivable hills and a column of the soil was taken from the hillside vineyard of Loma Ranch south of the town. The red clay loam soil was of varying thickness and underlaid by a mass of disintegrated granite.

Perris Valley lies southeast of Riverside at the western foot of the San Jacinto Mountains. It is about ten miles long and six wide, and has a variety of soils, as described by Professor Hilgard in the *Annual Report of the Agricultural Experiment Station* for 1894–95. The heavier soil from the center of the valley, about a mile east of the town of Perris, was selected and a column taken by Mr. F. E. Johnson.

The Valley of Escondido is a large and productive valley lying near the mountains. Its soil is a loam. A column was taken to a depth of twelve feet by Mr. F. E. Johnson in the vineyard of C. C. Katzenburger on the north side of the valley.

El Cajon Valley lies among the high mountains twenty-nine miles east of San Diego and has an area of six by four miles. The land is a reddish sandy loam and is very productive. A column twelve feet in depth was taken from near the cross-roads by Mr. F. E. Johnson.

TABLE 37.—HUMUS IN SOIL COLUMNS OF INTERIOR VALLEYS

	RIVERSIDE COUNTY				SAN DIEGO COUNTY											
	PERRIS VALLEY				FALLBROOK HILLS				ESCONDIDO VALLEY				EL CAJON			
Ft.	Soil Clay 14.59	Humus	Humus-Nitrogen in Humus	Soil	Soil Clay 4.22	Humus	Humus-Nitrogen in Humus	Soil	Soil Clay 6.93	Humus	Humus-Nitrogen in Humus	Soil	Soil Clay 10.45	Humus	Humus-Nitrogen in Humus	Soil
1	Loam.....	.35	1.66	.05	Red loam.....	.55	11.82	.03	Red loam.....	.47	6.27	.03	Red loam.....	.93	5.92	.05
2	Loam.....	.31	4.16	.03	Red loam.....	.36	3.12	.01	Red loam.....	.30	3.74	.01	Red loam.....	.36	3.88	.01
3	Loam.....	.57	3.69	.02	Red loam.....	.21	4.01	.01	Red loam.....	.12	4.68	.01	Red loam.....	.21	3.32	.01
4	Loam.....	.50	5.62	.03	Red loam.....	.13	2.16	.01	Red loam.....	.09	4.68	.01	Red loam.....	.07	7.00	.01
5	Sandy	.19	3.70	.01	Red loam.....	.20	2.31	.01	Sandy loam..	.08	.....	....	Red loam.....	.08	7.00	.01
6	Sandy	.17	3.30	.01	Red loam.....	.17	2.48	.01	Sandy loam..	.14	.....	....	Red loam.....	.07	7.00	.01
7	Sandy	.22	3.19	.01	Sandy	.16	1.76	.01	Sandy loam..	.07	.....	....	Red loam.....	.07	7.00	.01
8	Sandy	.13	5.40	.01		....	.....	....	Sandy loam..	.06	.....	....	Red loam.....	.06	7.00	.01
9	Sandy	.14	4.01	.01	Granitic	....	.....	....	Sandy loam..	.06	.....	....	Red loam.....	.06	.....	....
10	Sandy	.21	2.67	.01	sand	....	.....	....	Sandy loam..	.07	.....	....	Red loam.....	.06	.....	....
11	Sandy	.17	3.30	.01	debris	....	.....	....	Sandy loam..	.06	.....	....	Red loam.....	.06	.....	....
12	Sandy	.10	2.30	.01		....	.....	....	Sandy loam..	.04	.....	....	Red loam.....	.07	.....	....
Sum of per cents		3.66				1.73				1.56				2.10		
Average per foot		.30	3.62	.02		.15	4.02	.01		.13	4.84	.01		.13	6.08	.01
*Upper 3 feet:**																
Sum of per cents		1.33				1.12				.39				1.50		
Average per foot		.61	3.17	.03		.37	6.32	.02		.29	4.90	.02		.50	4.54	.02

* Range of most annual plant roots.

The surface soil of the column taken near Perris is badly deficient in humus, but in each of the three feet below there is a fair percentage. Green-manuring crops are called for. The hill lands of Fallbrook also are low in their percentages of humus and nitrogen and need nitrogen fertilizers (either through nitrates, stable manure, tankage, or dried blood) as well as good green-manure crops.

The column representing the Escondido Valley is very poor in humus and nitrogen, while that of El Cajon is better supplied, though still much below what is needed for good texture and fertility. Crops should respond to nitrate fertilization on both of these soils.

The humus in all of these soils is surprisingly low for valley lands that are as productive as these.

SUMMARY FOR SOUTHERN CALIFORNIA SOIL COLUMNS

The following are the averages obtained by combinations of the twenty-six columns, omitting the marsh of the Pomona cienega:

	Per cent
Average humus in surface foot	0.88
Average sum of per cents of humus in upper three feet	1.98
Average humus in each of upper three feet	0.66
Average nitrogen in humus of surface foot	5.53
Average nitrogen in humus of upper three feet	5.22
Average nitrogen in surface foot of soil	0.05
Average nitrogen in upper three feet of soil	0.04
Average nitrogen in each of twelve feet of soil	0.02

These percentages are all too low and indicate the great need of good green-manuring treatment for a number of years to build up the upper three feet of soil into a high fertility. This is needed more than phosphate fertilization.

There are but six of the twenty-five soils whose surface foot contains more than 1 per cent of humus; there are but five others that have more than 0.75 per cent, and there are five whose humus falls even below 0.50 per cent.

The lands represented by these columns from Southern California are under such continuous cultivation that the surface foot is hardly a proper unit of comparison; a depth of three feet

would be more nearly correct, for in that is usually found the mass of feeding roots, and no disturbing irregular conditions exist. The general average of the total amount in the three upper feet (sum of per cents) of the columns (omitting that of the Pomona cienega) is 1.98, or an average of 0.66 per foot. This is too small.

The Santa Ana adobe and Chino moist land have each above 4.50 and Mound Schoolhouse has 3.11 per cent, but all others fall below the latter. Six of the columns have more than 2 per cent each, while on the other hand three have each a sum of less than 1 per cent in the three feet, or an average of but 0.25 per cent per foot.

The humus in these soils is with a few exceptions not especially rich in nitrogen, and, as a consequence, the soil is but meagerly supplied.

SOIL COLUMNS OF THE NORTHEASTERN LAVA-BED REGION

The lava-bed region, comprising a large portion of the northeastern part of the state, reaches north from the Sierra Nevada mountains into Oregon and is a region of lava-bed plateaus and hills interspersed with occasional valleys that are capable of cultivation to a large extent in grain, some fruits, and alfalfa.

Honey Lake Valley.[6]—This valley with its large lake lies between the foot of the Sierras and the lava hills on the north, and has an elevation of about 4000 feet above sea-level. It is divided into the Honey Lake Valley proper and the East Side Valley, which extends from the lake eastward into the desert region.

Honey Lake occupies the greater part of the valley and is bordered on all sides by lands which are being brought under cultivation in grain and alfalfa, except on the east, where the soil is of a more sandy and alkali nature. A column of soil was taken to a depth of ten feet from near Standish on the north side of the valley; a large and luxuriant growth of alfalfa covered the adjoining fields.

[6] Described by Professor Hilgard in *Report of Agricultural Experiment Station*, 1891–92, p. 24.

Another column of soil, taken by Professor G. W. Shaw from a strong alkali tract bordering the lake on the east side near Amedee, contained but 0.25 per cent of humus in the first and 0.15 per cent in the second foot but none below that depth.

East Honey Lake Valley.—This desert-like region comprises that portion of Honey Lake Valley in Lassen County that reaches eastward from the lake into Nevada at an elevation of about one hundred feet more than the lands around the lake, and lies between hills of lava debris. The width is about fifteen miles, but increases much more toward the state line. The soil of the plain seems to be, for the most part, quite free from alkali salts, which appear only here and there on the surface; but toward the state line at lower levels the alkali is more abundant. On the north side of this plain the soil is quite level and sandy, with a reddish sandy subsoil.

A wide belt of alluvial land borders Skedaddle Creek in a depth of three or four feet near the creek. Beneath this there is, as shown in a well on the place of A. L. Spoon at Stacy Station, two feet of sand and twenty feet of a calcareous clay underlaid in turn by blue sand and clay. A column of soil was taken for examination from this land to a depth of twelve feet.

It is interesting to note here that a well on the place of Mr. Caudle, north of Stacy, exposed three feet of a reddish soil, three feet of sand, seven feet of boulders, and fifteen feet of white calcareous clay; below this appeared blue clay to a depth of 320 feet from the surface, water being reached at that depth.

In the center of the valley the surface of the land is in low ridges, the sandy soil being blown into hillocks, the soil being underlaid by a very compact gray silty soil to ten feet; then beneath that is ten feet of a fine sand, followed by ten feet of a coarse sand in which water is struck in wells. Beneath this lies a blue clay of fifty feet or more in thickness. A column of soil was taken in this land to twelve feet depth, four miles north of Calneva. On the south of the Western Pacific Railroad from Calneva to the mountains the soil is coarsely sandy.

The soil of Stacy is somewhat remarkable in having so high a percentage of humus in its second foot, and especially in having so much throughout the entire column. It compares well with

TABLE 38.—HUMUS IN SOIL COLUMNS OF HONEY LAKE VALLEY, LASSEN COUNTY

EAST HONEY LAKE VALLEY								HONEY LAKE VALLEY			
STACY				NORTH OF CALNEVA				STANDISH			
Soil [illegible] 11.29	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 19.50	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 14.58	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
[illegible]k loam....	.64	7.35	.05	Clay loam	.25	3.85	.01	Loam.....	.72	3.45	.03
[illegible]k loam....	1.26	4.68	.06	Clay loam	.10	tr.	tr.	Loam.....	.33	tr.	tr.
[illegible]dy.....	.45	6.22	.03	Clay loam	.14	.....	....	Loam.....	.17	.....	....
[illegible]dy.....	.47	6.60	.03	Clay loam	.17	.....	....	Whitish loam	.21	.....	....
[illegible]y.....	.44	7.05	.03	Clay loam	.13	.....	....	Whitish loam	tr.	.....	....
[illegible]dy.....	.39	6.40	.03	Clay loam	.13	.....	....	Whitish loam	....	.....	....
[illegible]m.....	.34	5.90	.02	Clay.....	.12	.....	....	Whitish loam	....	.....	....
[illegible]m.....	.27	7.40	.02	Clay.....	.10	.....	....	Whitish loam	....	.....	....
[illegible]m.....	.24	8.32	.02	Clay.....	.16	.....	....	Whitish loam	....	.....	....
[illegible]m.....	.24	7.08	.02	Clay.....	.15	.....	....	Whitish loam	....	.....	....
[illegible]m.....	.22	.....	....	Sand	.08	.....	....	Whitish loam	....	.....	....
[illegible]m.....	.20	.....	....	Sand	.07	.....	....	Whitish loam	....	.....	....
[illegible] per cents	5.16				1.60				1.43		
[illegible]e per foot	.43	6.70	.03		.13	.....	....		.13	.....	....
*[illegible]r 3 feet:**											
[illegible] per cents	2.35				.49				1.22		
[illegible]e per foot	.78	6.08	.05		.16	.....	....		.41	.....	....

*Range of most annual plant roots.

many soils of the more favored portions of the state. The humus is fairly rich in nitrogen, but the amount given to the soil is small.

The soil from the region north of Calneva contains very little humus even in the surface foot, but it is found throughout the entire column and is very poor in nitrogen. The humus is apparently derived from the debris and roots of the sagebrush and alkali weeds that grow on the plain.

With an abundant water supply and the turning under and humification of some good legume crop there is no reason why the lands of East Honey Lake Valley at their elevation of 4000 feet above sea-level should not produce crops suitable to that altitude as well as the lands of Imperial Valley which are below sea-level, though climatic conditions naturally would control the kind of crops grown.

The column taken from an alfalfa field near Standish on the north side of the lake is surprisingly low in humus below the

surface foot. The underlying whitish limy loam seems to have restricted the development of plant roots to the upper four feet. The humus is also poor in nitrogen and was probably derived from the meager roots of sage and alkali weeds.

A soil previously taken from the Susanville Meadows had only 0.33 per cent of humus, and another from two miles west of Amedee had but 0.29 per cent.

Madaline Plains.—Passing north from Honey Lake Valley across hills covered with beds of lava, we come to the Madaline Plains, which occupy an immense and almost level basin (probably once an inland lake) at an elevation of 5200 feet above sea-level. Its area is approximately 150 square miles, very irregular in outline, and bordered on all sides by lava hills. Its soil is a dark and very compact clay, underlaid at three or more feet by a light-colored marl of a hardpan nature and upwards of seventy-five feet in thickness, as shown in well-borings. A column of this soil four feet in depth was obtained from the plain to the westward of the place of W. C. Brockman. Previous analyses of other samples show fair amounts of phosphoric acid. Grass and grain are said to do well on this plain. The surface foot was found to contain 0.52 per cent of humus, and the second foot 0.60 per cent, but below this the clay was almost free from it. The soil contains about 0.04 per cent of humus-nitrogen.

Pitt River Valley.—Pitt River, with its source at the western foot of the Warner range of mountains, passes through a number of valleys as it flows westward into the Sacramento River. The town of Alturas is located in one of these valleys at the junction of the two forks of the river. The soil of the valley is chiefly meadowland with water at a depth of a few feet and partly grown in tules, but affording large alfalfa tracts. A column of six feet was taken from an alfalfa field near the town. The valley is bordered by lava-beds and hills. Goose Lake Valley to northward and reaching into Oregon has a similar meadowland soil reaching from the lake eastward to the foot of the mountains, where the disintegrated debris affords some higher land on which orchards are planted.

Klamath Lake Marshes.—A column from the tule marshes of Klamath Lake, Butte Valley, was obtained for us by Mr. L. S. Robinson for examination.

TABLE 39.—HUMUS IN SOIL COLUMNS OF PITT RIVER AND BUTTE VALLEYS

	PITT RIVER VALLEY, MODOC COUNTY, ALTURAS				BUTTE VALLEY, SISKIYOU COUNTY, KLAMATH			
Ft.	Soil Clay 29.60	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 11.00	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1	Clay.....	3.05	1.93	.06	Marsh loam..	3.75	9.15	.34
2	Clay.....	1.45	3.39	.05	Marsh loam..	3.20	7.10	.23
3	Clay.....	1.01	5.85	.06	Marsh loam..	3.02	9.07	.27
4	Clay.....	.87	3.22	.03	Marsh loam..	2.84	8.88	.25
5	Clay.....	.51	1.09	.01	Ashy loam† ..	.91	7.70	.07
6	Clay.....	.34	1.65	.01	Ashy loam† ..	.74	7.58	.06
7	Water	....	.....	....	Dark clay	.06	.....	....
8					Dark clay	fr.	.....	....
	Sum of per cents	7.23				14.52		
	Average per foot	1.20	2.85	.03		1.81	8.25	.20
	*Upper 3 feet:**							
	Sum of per cents	5.51				9.97		
	Average per foot	1.84	3.72	.06		3.32	8.44	.28

* Range of most annual plant roots.

† Infusorial earth.

Both of the above soils are rich in humus, though differing greatly in other respects. The Alturas is a clay soil under cultivation in alfalfa, and while its humus is poor in nitrogen the amount given to the soil is fair. On the other hand, the Klamath column is from tule-marsh lands, containing a larger proportion of decaying vegetable matter, and consequently is quite rich in humus. The latter is especially rich in nitrogen and as a consequence the soil is also well supplied in nitrogen through its upper four feet. The fifth and sixth foot are largely made up of diatomaceous earth in which the humus has suddenly diminished to less than 1 per cent.

Surprise Valley.—Eastward from Alturas, the Warner range of mountains separates the Pitt River Valley from Surprise Valley with its three large lakes. The land of the eastern side of this valley is strongly charged with alkali salts, but on the west the broad slope from the mountains to the lake presents excellent agricultural capabilities, the production of alfalfa seed being quite a prominent industry. A column of soil ten feet deep

(to water) was obtained two miles south of Cedarville with the assistance of Mr. W. L. Turner, and another column of four feet from the meadowland that forms a broad border to the lake, and in which water was struck at four feet.

TABLE 40.—HUMUS IN SOIL COLUMNS OF SURPRISE VALLEY, MODOC COUNTY

CEDARVILLE				CEDARVILLE			
Ft. Soil	Humus	Nitrogen in Humus	Nitrogen in Soil	Ft. Soil	Humus	Nitrogen in Humus	Nitrogen in Soil
Clay 10.97							
1 Loam	4.27	1.14	.05	Meadow loam	2.71	3.46	.09
2 Loam	1.25	3.36	.04	Meadow loam	2.10	4.62	.10
3 Loam	1.21	2.81	.03	Meadow loam	.86	8.02	.07
4 Loam	.93	2.26	.02	Meadow loam	.79	7.59	.06
5 Loam	.64	2.66	.02	Water	.....	.....	...
6 Loam	.63	2.67	.02				
7 Loam	.56	3.93	.02				
8 Loam	.60	2.33	.01				
9 Loam	.51	2.55	.01				
10 Loam	.36	4.72	.02				
Sum of per cents	10.96				6.46		
Average per foot	1.10	2.84	.03		1.62	5.92	.08
*Upper 3 feet:**							
Sum of per cents	6.73				5.67		
Average per foot	2.25	2.44	.04		1.89	5.37	.09

* Range of most annual plant roots.

The surface soil of the Cedarville loam is surpassed in its percentage of humus only by the black clay of Santa Clara and the marsh lands among all of the soils of the state thus far examined, and it ranks fifth with regard to the amount in the three upper feet. The percentage throughout the entire column of ten feet is quite high. This high humus content may be due to the alfalfa crops that have been produced for seed on this soil for a number of years past, as a soil from another locality near Cedarville examined ten years ago contained but 1.56 per cent in the surface foot. The humus is, however, remarkably weak in nitrogen, if such was its origin.

The meadow soil lying at a lower level is very similar to that of Alturas in its humus content.

SOIL COLUMNS OF THE "DESERT" PLAINS

The term "desert" is here applied to the extent of country with scant rainfall and having a vegetation of sagebrush and largely devoid of grasses; a country whose soils are usually rich in the mineral elements of plant food and which are remarkable for their fertility when properly cultivated and abundantly irrigated. The reason for this fertility lies partly in the fact that the humus, though small in amount, is with its nitrogen well distributed throughout a depth of twelve feet and more, in a soil whose sandy or silty texture permits deep rooting of plants.

The desert lands are interspersed with mountain ranges separated by valleys of greater or lesser extent. Some of these valleys have with irrigation been brought under cultivation and settlement and from these a few soil columns were secured.

Imperial Valley.—This newly settled part of the state, once the bed of Salton basin which on drying-up became a desert until reclaimed by irrigation, largely lies below the level of the sea. Its soils, derived from the sediment of the Colorado River,

TABLE 41.—HUMUS IN SOIL COLUMNS OF IMPERIAL VALLEY, IMPERIAL COUNTY

	IMPERIAL				EL CENTRO			
Ft.	Soil Clay 50.43	Humus	Humus-Nitrogen in Humus	Soil	Soil Clay 47.42	Humus	Humus-Nitrogen in Humus	Soil
1	Silty clay.....	.26	6.14	.02	Silty clay.....	.30	5.15	.02
2	Silty clay.....	.24	3.51	.01	Silty clay.....	.23	5.49	.01
3	Silty clay.....	.21	3.34	.01	Clay.....	.22	6.38	.01
4	Clay.....	.19	4.43	.01	Clay.....	.21	4.54	.01
5	Silt.....	.17	6.61	.01	Clay.....	.32	4.39	.01
6	Silt.....	.21	4.01	.01	Clay.....	.27	5.20	.01
7	Clay.....	.22	3.83	.01	Clay.....	.26	4.86	.01
8	Clay.....	.15	4.68	.01	Clay.....	.31	4.08	.01
9	Silt.....	.14	4.01	.01	Clay.....	.28	5.01	.01
10	Silt.....	.13	5.40	01	Clay.....	.32	3.51	.01
11	Silt.....	.10	8.42	.01	Clay.....	.29	2.91	.01
12	Clay.....	.14	4.01	.01	Clay.....	.20	5.62	.01
Sum of per cents		2.16				3.21		
Average per foot		.18	4.86	.01		.27	4.76	.01
*Upper 3 feet:**								
Sum of per cents		.71				.75		
Average per foot		.24	4.33	.01		.25	5.67	.01

* Range of most annual plant roots.

have a peculiar light pinkish tint and are made up of alternating strata of silt and a very plastic and impervious clay of varying thicknesses. When this clay forms the surface soil, the difficulties of cultivation and irrigation are very great; but if the clay lies at a depth of several feet below the surface of a silty soil then the reverse is true. This peculiar type of land is represented in the series by two columns of soil, one from the vicinity of Imperial and the other from near El Centro; these and that from Coachella were taken by Mr. F. E. Johnson.

Mojave River Mesa.—The mesa or plain is formed by accumulation of granitic debris from the Sierra Madre Mountains on the south and reaches far out toward Barstow, San Bernardino County. This debris is coarse and quite compact, and in the neighborhood of Victorville is said to have a thickness of thirty-five feet or more. It is here overlaid by about three feet of a gray sandy soil, also quite compact and supporting a sparse vegetation of weeds. A column of eleven feet was obtained three miles west of Victorville. The soil was found to contain but 0.13 per cent of humus in the surface foot, 0.14 per cent in the second, 0.10 per cent in the third, and 0.08 per cent in the coarse sand of the fourth foot. There were but traces of nitrogen in the humus. The soil has 11.05 per cent of clay.

Coachella Valley.—A column was obtained from the vicinity of Coachella and represents the higher and more sandy lands that bordered the old Salton Lake of the Imperial country.

Owens River Valley.—The agricultural lands of this valley lie chiefly on the west side of Owens River and are formed of the debris of the adjoining Sierra Nevada. A column of soil was secured through the kindness of Mr. W. K. Winterhalter of San Francisco.

It was to be anticipated that the soils of what are known as the desert plains of the eastern and southeastern part of the state would be very poor in humus because of their very sandy nature, together with small rainfall, extreme summer heat and scant vegetation, but it was a surprise to find that humus occurred at depths of twelve or more feet below the surface. The soil poorest in humus is that from the mesa plain just west of Victorville, in which plant roots were found in a depth of three feet only, the underlying material being too compact for root

TABLE 42.—HUMUS IN SOIL COLUMNS OF OTHER VALLEYS

	COACHELLA VALLEY RIVERSIDE COUNTY COACHELLA				OWENS VALLEY INYO COUNTY BISHOP			
Ft.	Soil Clay 16.90	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil	Soil Clay 6.28	Humus	Humus-Nitrogen in Humus	Humus-Nitrogen in Soil
1	Loam	.32	5.27	.01	Sandy	.31	3.55	.01
2	Loam	.22	5.74	.01	Sandy	.23	.....	....
3	Loam	.14	6.02	.01	Sandy	.19	.....	....
4	Loam	.13	1.08	tr.	Sandy	.19	.....	....
5	Loam	.10	1.40	tr.	Sandy	.13	.....	....
6	Loam	.14	4.01	.01	Sandy	.07	.....	....
7	Loam	.11	5.11	.01	Sandy	.08	.....	....
8	Loam	.14	4.01	.01	Sandy	.08	.....	....
9	Loam	.12	4.68	.01	Sandy	.08	.....	....
10	Loam	.15	5.62	.01	Sandy	.06	.....	....
11	Loam	.16	6.14	.01	Sandy	.08	.....	....
12	Loam	.13	4.32	.01	Sandy	.06	.....	....
Sum of per cents		1.86				1.56		
Average per foot		.15	4.45	.01		.13	.....	....
*Upper 3 feet:**								
Sum of per cents		.68				.73		
Average per foot		.23	5.68	.01		.24	.....	....

* Range of most annual plant roots.

penetration. It, however, supported a growth of yucca and desert weeds, and on the same mesa, near Hesperia, with presumably the same soil though deeper, there are a few orchards. A glance at the table shows that there is nearly the same percentage of humus in the first foot of each of the columns and very little difference in the total amount in the upper three feet.

The very unequal distribution in the El Centro column is somewhat surprising, for it might readily be supposed that the small amount in the surface foot would indicate that there was scarcely any in the lower depths; whereas we find higher percentages in the fourth, fifth, eighth, and tenth foot respectively than in either of the upper three feet. It is interesting to note that there is more in the lower half of the column than in the upper. The humus of these columns is not quite as rich in nitrogen as are the soils from other parts of the state, and that of the Bishop column is extremely low. The nitrogen of the soil is not more than 0.01 per cent, or about 400 pounds per acre-foot.

GENERAL SUMMARY

INDIVIDUAL SOIL COLUMNS HAVING THE HIGHEST HUMUS CONTENT

In looking over the 109 columns of soil taken from the various agricultural regions of the state, we find that eighteen have each more than 2 per cent of humus in the surface foot, and thirty-two others have more than 1 per cent, the remaining fifty-nine having less than that.

The following twenty-five localities are worthy of special mention, for in their respective columns more than 1 per cent of humus is found in each individual soil layer to depths of three to seven and even nine feet below the surface; they are ranged according to depth.

TABLE 43.—COLUMNS WITH 1 PER CENT OF HUMUS IN THREE OR MORE INDIVIDUAL FEET

Soil	Locality	County	Depth
Tule	Stockton	San Joaquin	9 ft.
Loam	Arroyo Grande Valley	San Luis Obispo	7 ft.
Loam	Arroyo Grande Seed-farm	San Luis Obispo	7 ft.
Clay loam	Lompoc Seed-farm	Santa Barbara	7 ft.
Loam	Santa Rosa	Sonoma	6 ft.
Adobe	Berkeley	Alameda	6 ft.
Loam	Russian River	Sonoma	5 ft.
Clay loam	Walnut Creek	Contra Costa	5 ft.
Adobe	El Verano	Sonoma	4 ft.
Loam	Yountville	Napa	4 ft.
Clay	Gilroy	Santa Clara	4 ft.
Loam	Chino	San Bernardino	4 ft.
Loam	Klamath (tule)	Siskiyou	4 ft.
Loam	Glenn	Glenn	3 ft.
Sandy	Chico	Butte	3 ft.
Clay loam	Davis	Yolo	3 ft.
Clay	Farmington	San Joaquin	3 ft.
Loam	Newcastle	Placer	3 ft.
Loam	Kenwood	Sonoma	3 ft.
Adobe	San Ramon	Contra Costa	3 ft.
Clay	Santa Clara Seed-farm	Santa Clara	3 ft.
Loam	Pomona Cienega	Los Angeles	3 ft.
Clay	Santa Ana	Orange	3 ft.
Clay	Alturas meadow	Modoc	3 ft.
Loam	Cedarville	Modoc	3 ft.

A number of other localities very nearly come into the list as their upper two feet have more than 1 per cent and the third falls a little below. It will be noted that these results are not confined to any particular soil type but that all types from sandy to heavy clay adobe are represented in the list.

If the humus of the upper three feet be equally distributed through that depth we will find that nine of the columns have each an average of more than 2 per cent of humus in

TABLE 44.—SOIL COLUMNS HAVING THE HIGHEST HUMUS PERCENTAGES

IN FIRST FOOT	Per cent	AVERAGE OF UPPER THREE FEET	Per cent	AVERAGE OF ENTIRE COLUMN OF 10 OR 12 FEET	Per cent
kton tule	14.10	Stockton tule	16.68	Stockton tule	6.81
ona Cienega	6.26	Pomona Cienega	3.67	Arroyo Grande	1.39
a Clara adobe	4.43	Santa Clara adobe	3.63	Santa Clara (10 feet)	1.33
rville	4.29	Klamath marsh	3.32	Pomona Cienega	1.28
yo Grande seed-rm	3.78	Cedarville	2.25	Arroyo Grande seed-farm	1.27
nath marsh	3.75	Gilroy	2.23	Gilroy	1.14
ras meadows	3.05	Arroyo Grande	2.16	Cedarville (10 feet)	1.10
y	2.76	Arroyo Grande seed-farm	2.15	Lompoc seed-farm	1.09
rville meadows	2.71	Berkeley adobe	2.01	Berkeley	1.04
rville	2.64	Yountville	1.98	Russian River	1.01
poc seed-farm	2.50	Cedarville meadows	1.89	Yountville	.95
yo Grande	2.50	Lompoc seed-farm	1.86	Santa Rosa	.92
a Ana adobe	2.42	Alturas meadow	1.84	El Verano (10 feet)	1.00
o moist land	2.31	Kenwood	1.74	Walnut Creek	.80
rood	2.25	El Verano adobe	1.71	Hayward	.77
erano adobe	2.14	Farmington	1.65	Davis Univ. Farm	.75
eley adobe	2.13	Santa Ana adobe	1.63	Watsonville	.74
ington	2.04	Russian River	1.58	Chico	.73
ville	1.97	Chino	1.52	Vacaville	.71
a Rosa	1.95	Glenn	1.51	Glenn	.69

the upper three feet, and twenty-five others have an average of more than 1 per cent, all others falling below the 1 per cent. In the distribution of the humus through the entire twelve feet of the columns there are ten which thus give an average of more than 1 per cent for each foot, and twenty-five others whose average is about one-half of 1 per cent.

In the following table we have placed the names of the twenty localities which have as much as 1.95 per cent in the surface foot, and the twenty which rank highest in averages of the upper three feet and in the entire column of ten or twelve feet.

Composite Columns of Agricultural Regions

In the following table are given the averages of each of the agricultural regions embracing all of the 109 columns representing the state at large, taken from thirty-seven counties. The tule marshes of Stockton, Pomona, and Klamath are placed in a column by themselves. In some of the individual columns that form the composite for each region either a depth of twelve feet was not secured or the humus itself was not found to that depth.

The marsh lands are naturally richest in humus because of the large amount of decaying vegetable matter they hold. But next to these we find that the Coast Range valleys have the highest amount in the surface foot, the upper three feet, and in the entire column respectively. The lava-bed valley and meadow lands are but little above the Sacramento Valley in amount of humus, while the San Joaquin Valley falls behind Southern California. The "desert" plains naturally are lowest of the eight groups, but it is interesting to note that in the quite even distribution throughout the column there is a larger amount in the lower six feet than is found in the lower six feet of either the San Joaquin Valley or the lava-bed valleys.

In the foothill and lava-bed valleys the upper two feet hold one-half of the total humus; in the desert lands one-half of the humus is distributed through the upper five feet of soil, while in each of the other columns the upper three feet holds one-half of the humus.

The first foot of the desert lands contains but about one-eighth of the total amount of humus of the column; that of the Coast Range valleys and the marshes, a little more than one-fifth; while in the other regions the upper foot holds from one-third to one-fourth of the total amount found in the respective columns.

On glancing at the table the attention is first called to the depth of twelve feet to which humus reaches in all of the com-

TABLE 45.—COMPOSITE AVERAGES OF AGRICULTURAL REGIONS (IN PERCENTAGES)

Depth	Sacramento Valley 18 columns	San Joaquin Valley 23 columns	Coast Range Valleys 24 columns	Southern California 25 columns	Sierra Nevada Foothills 3 columns	N.E. Lava Beds Valleys 8 columns	"Desert" Plains 5 columns	Tule Marshes 3 columns
1st ft.	1.04	.80	1.94	.88	1.12	1.55	.26	8.04
2nd ft.	.75	.51	1.47	.65	.71	.92	.19	8.59
3rd ft.	.58	.37	1.13	.45	.57	.48	.17	7.05
4th ft.	.45	.25	.93	.37	.39	.40	.25	5.52
5th ft.	.36	.23	.77	.31	.18	.21	.18	2.65
6th ft.	.32	.17	.67	.27	.14	.18	.13	1.45
7th ft.	.23	.14	.59	.25	.18	.13	.13	.78
8th ft.	.19	.10	.49	.19	.10	.12	.14	1.64
9th ft.	.18	.18	.41	.16	.....	.11	.12	.68
10th ft.	.17	.06	.39	.16	.....	.09	.13	.30
11th ft.	.16	.06	.27	.13	.....	.03	.15	.21
12th ft.	.15	.04	.32	.11	.....	.03	.13	.29
In 12 feet								
Sum of humus per cents	4.58	2.91	9.38	3.93	3.39	4.25	1.98	37.20
Nitrogen in humus	5.45	6.53	5.15	5.54	5.64	3.69	4.69	5.63
Nitrogen in soil....	.03	.02	.04	.02	.03	.03	.01	.02
*In upper 3 feet**								
Sum of humus per cents	2.37	1.68	4.54	1.98	2.40	2.95	.62	23.68
Nitrogen in humus	5.79	6.27	5.13	5.74	5.40	3.79	4.97	5.75
Nitrogen in soil....	.04	.04	.07	.03	.05	.05	.01	.44
In surface foot								
Nitrogen in humus	5.68	6.08	5.43	6.50	5.93	3.53	5.03	6.35
Nitrogen in soil....	.05	.05	.10	.05	.07	.05	.02	.47

* Range of most annual plant roots.

posite columns except that of the Sierra Nevada foothills, the lava-bed meadows and the tule marshes, where, because of the underlying country-rock on the one hand and of water on the other, the depths are limited to eight, ten and seven feet respectively. Seventy-five of the columns have a depth of twelve feet, eleven others a depth of ten feet, and eight a depth of nine feet. In some of the columns the amount of humus is so high in the twelfth foot, especially in that of the valleys of the Coast Range, as to leave no doubt of its being found at a greater depth had

the examination been made. In fact, the column of Fort Romie was carried through fifteen feet, and 0.41 per cent of humus with 6.83 per cent of nitrogen was found in the lowest foot.

The next point of interest is the small amount of humus in the first foot of each of the columns excepting those of the meadowlands and the tule marshes. This is especially noticeable in the composite of the San Joaquin Valley and in that of the "desert" plains. The general average of the surface foot for all of the columns, excluding the marshes, is 1.16 per cent.

Another point of special interest is the gradual diminution of humus percentage downward in each of the composite columns with an occasional slight increase, as is seen in the eleventh foot of the Sacramento Valley and in the twelfth foot of the Coast Range valleys. This decrease indicates smaller amounts of humus-forming vegetable material, presumably the roots of plants, in each successive foot downwards, the main mass of the root systems being in the upper three or four feet.

Averages of Three Upper Feet.—A depth of one foot in California does not in reality represent the soil which is at least three feet deep, and it would not be correct or fair to the cultural possibilities of the land to draw conclusions from the humus of the first foot alone. It is very true that its presence to the extent of several per cent near the surface is of special importance in maintaining proper physical textural conditions for aeration, avoidance of crusts and easy penetration of water, but it is of as great importance that there should be several per cent of humus in each of the upper several feet; for in arid regions it is below the first foot and away from hot and dry soil that the feeding roots of plants prefer to carry on their activities, and it is in the upper three feet that the main mass of fine feeding roots are usually located, and where they must secure the needed plant food supplied by the humus. This not only protects the roots but gives to them a far greater feeding area which is enlarged with the extension of the humus downward. The summations for three feet are given at the foot of the table.

Sacramento Valley.—This valley, represented in the above table by a composite column of eighteen individual columns, is not only richer than the San Joaquin Valley in the first foot in

humus, but in every foot of the entire column to a depth of twelve feet. One half of the total amount is held in the upper three feet. Its first foot contains a little less than that of the Southern California column, but in the upper three feet and in the entire column there is more. The percentage in the first foot is too small and clearly shows the need of being increased by a system of growing and turning under of green crops. With this to encourage the growth of the young grain and trees, the lower portion of the column will afford humus-nitrogen and other plant food for the roots that find their way downward to twelve or more feet as was the case with wheat and barley roots on the University Farm at Davis. In the latter soil the humus of the first foot was only 0.85 per cent and that of the second foot 1.49 per cent, and the ordinary yield had been but from twelve to fourteen bushels of wheat per acre before the University bought the property. By proper methods of treatment and without irrigation or fertilization the agronomist in charge, Professor G. W. Shaw, secured a yield of 40.4 bushels of wheat per acre as an average of three years, during which time the average for the state was but 14.5 bushels.[7]

The humus-nitrogen content of the upper three feet of the Sacramento composite column is 5.79 per cent of the humus which thus gives 0.04 per cent to the soil. This is approximately 1600 pounds of nitrogen per acre for each foot in depth.

San Joaquin Valley.—The composite of twenty-three columns from the San Joaquin Valley shows humus percentages much below those of other regions, both in the surface foot (0.80 per cent) and in each foot of the entire column. The sum of 3.11 per cent, if contained in the upper foot of the three feet, would be a fair amount, though much below that of other regions. The low percentages may be due in part to the presence of alkali salts in some of the soils examined, also to a more arid climate of far less rainfall than in other regions, and to a less luxuriant vegetation upon the decay of whose roots the amount of humus is dependent.

Although this humus percentage is so low in the upper part of the soil, yet a proper system of deep plowing to break up any

[7] Bull. no. 211, Cal. Agr. Expt. Sta.

tendency to form a plowsole and to make the soil loose and of good texture for a downward development of the grain roots, which may thus secure the benefits of the humus, would tend greatly to increase the grain yields of the valley. This was shown in the experiments of Professor G. W. Shaw at Ceres and Tulare,[8] where during a period of three years by this method the average yield of wheat was thirty-five and thirty-three bushels respectively, during which period the average wheat for the state was 14.5 bushes per acre. No irrigation or fertilization was used in his experiments.

The humus-nitrogen of the upper three feet of the composite column is 6.27 per cent of the humus, which is higher than in any of the other composite columns in the table. In the soil itself, however, there is but an average of 0.04 per cent, or 1600 pounds per acre-foot.

Sierra Nevada Foothills.—The composite of three columns from the Sierra Nevada foothills shows more humus in the first foot than in that of the Sacramento Valley or Southern California. That of the second foot is, however, somewhat less, and there is a greater decrease in the lower part of the column, the sum being but 3.39 per cent in the eight feet. More than one-half of the humus is held in the upper three feet.

The humus-nitrogen in the upper three feet of the composite column is 5.4 per cent of the humus, or 0.05 per cent in the soil, and is equivalent to 2000 pounds for each acre-foot in the three feet.

Coast Range Valleys.—The composite column of the twenty-four soils of the valleys of the Coast Range shows a general average of nearly 2 per cent of humus in the surface foot and thus is far above each of the other columns, except the marshes and meadowlands. Not only that, but it is the only composite column of the uplands which has more than 1 per cent in the subsoils immediately below the first foot. The percentage of humus in each of the succeeding feet throughout the twelve feet is also higher than in any other of the composite columns; the twelfth foot has nearly one-half of 1 per cent and the sum of the entire column is 9.38 per cent. The humus is not as rich in nitrogen

[8] Bull. No. 211, Calif. Agr. Exp. Sta.

as that of the San Joaquin or Southern California, and the amount of organic nitrogen in the soil is below the 0.05 per cent regarded as necessary for fertility.

Southern California.—The soils of the valleys of Southern California represented by the composite of twenty-five columns have about the same humus content in the first foot and in the upper three feet as was found in similar parts of the columns from the Sacramento Valley and the foothills, but are far behind those of the Coast Range valleys. The humus is well distributed downward to twelve feet, and as with the Sacramento soils affords an excellent and large feeding area for plant roots; every encouragement should be given crops to take advantage of this by sending their roots deep into this fertile soil mass. The upper three feet contains a little less than one-half of the total humus.

The humus of the first foot is too low for the maintenance of good physical condition and careful attention should, as a rule, be given to the turning under of green crops and the humification of the same.

The humus in the upper three feet contains 5.74 per cent of nitrogen, but this gives only the small amount of 0.03 per cent to the soil: this is equivalent to about 1200 pounds per acre-foot, which under the influence of bacteria gradually becomes available for plants.

"Desert" Plains.—The desert lands represented by a composite of five columns from the valleys of Imperial, Coachella, Owens River, and Mojave River are very low in humus in their upper several feet, as is to be expected from the meagerness of the natural humus-forming vegetation. One-half of the humus is held in the upper five feet instead of in three, as is the case with other regions. The presence of so much humus in the twelfth foot is a matter of some surprise, for the lands seem usually quite deficient in natural moisture other than hygroscopic for hundreds of feet in depth. The amount of humus in the twelfth foot is one-half that of the first foot. The humus of the upper three feet contains but 4.97 per cent of nitrogen, which gives but 0.01 per cent of organic nitrogen in the soil: this is equivalent to about four hundred pounds per acre-foot, which is very little.

Lava-bed Region.—The valley lands of the Lava-bed region

of the northeastern part of the state have in the composite of eight columns a high percentage of humus, not only in the first foot but in the second. This is natural as the soils are moist from underlying water and there is a strong vegetation whose roots penetrate deeply. The total sum of humus percentages in the twelve feet is 4.25 per cent, the upper three feet holding more than one-half of it. The humus is poorer in nitrogen than in any of the regions except the desert, the average in the upper three feet being 3.79 per cent, or 0.05 per cent in the soil.

Tule Marshes.—The tule marshes near Stockton and Klamath and the Pomona cienega have extremely high humus percentages in each of the four upper feet, and the humus is also quite high through the column of seven feet, all derived from the large amount of decaying tule roots. The humus-nitrogen of the upper three feet is, however, only 5.75 per cent in the humus or 0.44 per cent in the soil; the latter is much higher than found in any of the columns.

Nitrogen in the Humus and in the Soil

Nitrogen exists in the soil partly in the free state in the air that permeates the soil; partly in the vegetable and animal material that has not undergone humification; partly in the humified vegetable and animal matter; and partly as nitrates soluble in water, and hence very variable in amount from day to day and liable to be lost by drainage. That the unhumified material in the soil does not yield its nitrogen to the plants until after complete humification has been shown by the experiments of Professor Hilgard, whose conclusions are as follows:

"It thus appears that although the nitrogen of the unhumified organic matter constituted about 40 per cent of the total in the original soil, it would during the entire year have contributed only to an insignificant extent to the available nitrate supply; while the fully humified 'matiere noire' contributed fourteen times as much. During the growing-season of four or five months the unhumified organic matter would have yielded practically nothing to the crop."[9]

[9] Soils (Macmillan & Co., 1906), p. 360.

The humus itself then is the most reliable source of nitrogen, keeping it in reserve to be given to the roots of plants by degrees by ammonifying and nitrifying bacteria and at the time when most needed, namely, in the growing season. The fertilizing value of humus depends, as has already been remarked, upon the amount of nitrogen that it contains and which may be changed to ammonia and nitrates through the agency of bacteria and given to the soil and plant. The nitrogen content naturally varies according to the nature of the materials from which the humus was formed and to any diminution that may have occurred from bacterial action or other causes, and we therefore find great differences in one and the same column of soil. Sometimes the difference is very great between one foot and the next, for which it is difficult to account.

Nitrogen in Humus.—More than one thousand of these nitrogen determinations in the humus of the soil columns have been made and the results were found to vary from 1 per cent to 24 per cent, but the greater number were from 4 per cent to 6 per cent.

The highest percentage of nitrogen in humus was 24.10 per cent, found in the eighth foot of the Berkeley adobe column, and in this were three other levels with more than 10 per cent. all of which were below the sixth foot. The column from Kenwood, Sonoma County, had in its sixth foot 23.2 per cent, while two others of its series had above 10 per cent. The sixth foot of the Santa Paula soil had 20.5 per cent and in the fifth and ninth foot there was more than 10 per cent. The humus of the entire soil column from Fullerton, from the place of Dr. S. S. Twombly, has the credit of being richer in nitrogen than any soil thus far examined, the fifth foot having 20.5 per cent, the eighth and tenth having more than 19 per cent each, the third 18.4, and the others above 10 per cent, excepting the second foot which has 7.8 per cent; the general average of the column is 15 per cent. The amount of humus is, however, quite small throughout the column, and hence the amount of humus-nitrogen given to the soil is but 0.05 per cent. The humus of the Kearney Park soil is another notable example of rather high percentages of nitrogen, as in each of the seven feet below the

upper foot there is more than 10 per cent; but here again the amount of humus is small. The Chico column should also be mentioned, as from the fifth to the twelfth the humus of each foot contains from 10 to 14 per cent of nitrogen, except the ninth which has 9.5 per cent.

In the one thousand determinations of nitrogen there were but sixty-four instances, or about 6.4 per cent, where the humus contained more than 10 per cent of nitrogen: fourteen of these have from 15 to 20 per cent and six have above 20 per cent. The general average of all, including the marshes, is 5.92 per cent for the first foot, 5.60 per cent for the upper three feet and 5.57 per cent for the entire depth of twelve feet.

The humus of the surface foot of the composite of Southern California soils is richer in nitrogen than that of any of the other regions, though nearly equalled by that of the tule marshes. That of the lava-bed valleys is poorer in nitrogen than any.

When we consider the upper three feet of the composite columns we find that the humus of the San Joaquin Valley is much the richest and that of the lava beds again the poorest. Four of the eight columns fall below the general average for the state. The same is true for the averages of the twelve foot columns.

The differences in the percentages of nitrogen in the humus of the upper three feet and of the total column are not very great, especially in the valleys of the Coast Range, where the two are very nearly the same; in the Sacramento Valley, Southern California lava beds and the desert plains the average in the column is considerably less.

Organic Nitrogen in the Soils.—It is well to remark here that 0.10 per cent of humus-nitrogen in the upper foot of a humid soil is regarded as an ample supply for fertility, while in the arid region with its deeper soil, deeper humus and deeper root penetration, one-half of that amount, or 0.05 per cent in each of the three upper feet is considered sufficient for many years, because the roots are in a deeper feeding area than in the humid region, and bacterial activity is greater and deeper. This percentage would mean 2000 pounds of nitrogen per acre in each foot.

The marsh or tule soils of the state have very high amounts of nitrogen, as shown in the Stockton tule (0.83 per cent), Klamath tule (0.34 per cent), and the Pomona cienega (0.25 per cent). The nitrogen is, however, less available than that of the dry uplands, and a comparison cannot be made. The two soils from the Arroyo Grande Valley, including the Routzahn seed-farm, are highest among the other soil columns with their 0.16 per cent of nitrogen each; the next highest are Gilroy with 0.15 per cent; Berkeley and Farmington each with 0.14 per cent; Burpee seed-farm of Lompoc, Vaca Valley, and Kenwood each with 0.13 per cent; and El Verano, Santa Maria, Chico, Yountville, and Chino each with 0.11 per cent. Newcastle soil has 0.10 per cent, while all others have less than that. The results show most certainly that the lands represented by these fourteen soils should not need fertilization with nitrate fertilizers for many years.

Nine of the soils have but 0.01 per cent of humus-nitrogen in the first foot, seven have but 0.02; forty-six or nearly half of the columns have less than 0.05 per cent. and hence are much below the desirable percentage of nitrogen. The average of the first foot of all of the columns, except the marshes, is about 0.05 per cent.

Some of the upland soils are quite rich in organic nitrogen in the upper three feet, the true soil of the arid region. The adobe of Berkeley is the richest with its 0.13 per cent or approximately 15,000 pounds per acre in a depth of three feet. Eight columns have averages of 0.10 and upward, viz., the two Arroyo Grande soils, Gilroy, Chico, Farmington, Kenwood, Newcastle, and Cottonwood. Thirty-one columns have averages of from 0.06 to 0.10 per cent, all others being below this amount. In other words we find that more than half of the columns have less than the 0.05 per cent of organic nitrogen in their upper three feet which is considered necessary for fertility. Many have but little more than traces of nitrogen.

In the entire column of twelve feet we find that there are eleven upland localities that have averages of as much as 0.05 per cent, and among these Berkeley and Arroyo Grande columns stand highest with averages of 0.08 per cent or approximately

38,000 pounds of organic nitrogen distributed through the depth of twelve feet.

HUMUS IN SOILS OF DIFFERENT TEXTURE

We have grouped together in the following table the humus percentages of soil columns having similar texture and similar characters in order to ascertain whether these have any influence upon the amounts of humus. For the textural classification of the soils we have used that of Professor Hilgard,[10] the basis of which is the percentage of clay in the soil. Thus soils with 3 per cent and less are classed as very sandy, those with from 3 to 10 per cent of clay as sandy, with from 10 to 15 per cent as sandy loams, with from 15 to 25 per cent as clay loams, with 25 to 35 per cent of clay as clay soils, and those with more than 35 per cent of clay are classed as heavy clays, among which are the adobes of California and other states of the arid west.

TABLE 46.—AVERAGE OF HUMUS IN LANDS OF DIFFERENT TEXTURE AT VARIOUS DEPTHS

	Very sandy 1-3% clay 9 columns Per cent	Sandy 3-10% clay 15 columns Per cent	Sandy loam 10-15% clay 21 columns Per cent	Clay loam 15-25% clay 23 columns Per cent	Clay 25-35% clay 8 columns Per cent	Heavy adobe -35% clay 10 columns Per cent
1 ft.	.62	.81	.97	1.33	2.03	1.56
2 ft.	.50	.62	.77	.98	1.25	1.23
3 ft.	.37	.43	.55	.73	1.11	.95
4 ft.	.31	.35	.43	.63	.89	.61
5 ft.	.29	.35	.37	.48	.68	.43
6 ft.	.21	.35	.31	.41	.52	.37
7 ft.	.20	.31	.30	.34	.53	.28
8 ft.	.14	.26	.24	.28	.40	.21
9 ft.	.12	.20	.19	.24	.37	.17
10 ft.	.07	.19	.20	.22	.29	.17
11 ft.	.04	.15	.14	.20	.19	.14
12 ft.	.03	.16	.12	.19	.25	.13
Sum of per cents:						
Upper 3 feet....	1.49	1.86	2.29	3.04	4.39	3.74
Upper 6 feet....	2.30	2.91	3.40	4.56	6.48	5.15
Lower 6 feet....	.60	1.27	1.19	1.47	2.03	1.10
Entire column..	2.90	4.18	4.59	6.03	8.51	6.25

[10] Soils (Macmillan & Co.), p. 84.

It is interesting to note in each of these composite columns of soils the quite regular decrease in the amount of humus from the surface to the twelfth foot, thus indicating that in each the humus has been derived from the decay of plant roots rather than from vegetable material deposited during the building-up of the soil strata. It also gives testimony to the deep rooting of plants of all kinds, notably grasses and weeds during the ages that have passed.

Another interesting point is the regular increase in the humus percentages from a minimum in the very sandy to the maximum in the clay and then a decrease in the adobe clays, not only in the surface foot of these composite soil columns but also in each succeeding foot down to the twelfth, the only exceptions being slight ones in the sandy loam series which are a little less than in the sandy.

It is clearly evident, then, that as a rule the clay soils, excepting the adobe clays, of the state have a higher percentage of humus than any other class; and that the humus content in the series increases with the increase in clay up to a certain point when there is a decrease.

The tables show that the lower half of the heavy adobe clays has a smaller percentage of humus than any other class except the very sandy; the inference being that the close, compact, heavy clay strata have prevented the extension of plant root systems to the lighter soils.

It will also be noted that one-half of the total humus in each of the composite columns is held in the upper three feet, with the exception of the sandy, in which it is held in four feet.

Comparison of Individual Heavy Black Adobe Clay Soils

The heavy clay soils known as adobe clay and containing from 35 per cent of clay upward to as high as 62 per cent are found in isolated areas throughout the state, the largest being in the region of Stockton. They form a distinct class possessing peculiar physical properties. The surface soil is usually black to a depth of three or more feet, changing to a lighter color below and generally resistant to the easy movement of water, plant roots, and tillage implements, though the roots of ordinary

weeds have been followed to the depth of eleven feet below the surface, and alfalfa roots have been observed at a depth of twenty-six feet in the adobe of Berkeley. It is extremely plastic when wet, but when dry it absorbs water with extreme slowness. Because of the black color it was supposed that the humus content would be found to be quite high in all localities, but the disappointment following the examination of many columns has induced us to present them in a table for comparison; the figures for humus and for amount of clay are taken from the report on the several agricultural regions already given. The "adobe" soils in which there is less than 35 per cent of clay are omitted from the table.

TABLE 47.—PERCENTAGE OF HUMUS IN COLUMNS OF BLACK ADOBE CLAY

Depth	Santa Clara 59% clay	Berkeley 44% clay	East of Willows 48% clay	Walnut Creek 35% clay	San Ramon 45% clay	South of Yuba City 39% clay	Stockton 57% clay	Kings City 35% clay	South of Dixon 62% clay	West of Tracy 40% clay	Ber [illegible]
1 ft.	4.43	2.13	1.72	1.42	1.23	1.20	1.16	1.15	.86	.82	.60
2 ft.	3.66	2.04	1.16	1.44	1.28	.21	.76	.90	.62	.70	.40
3 ft.	2.80	1.84	.94	1.16	1.08	.18	.50	.61	.34	.30	.40
4 ft.	.61	1.90	.62	1.12	.84	.18	.22	.25	.28	.12	.17
5 ft.	.27	.95	.36	1.08	.81	.11	.22	.52	.30	.19	.06
6 ft.	.20	1.06	.26	.72	.75	.10	.41	.41	.30	.09	.06
7 ft.	.62	.48	.22	.60	.29	.08	.11	.43	.30	.....	.09
8 ft.	.23	.37	.20	.60	.20	.12	.09	.37	.26	.00	.06
9 ft.	.30	.36	.14	.42	.14	12	.08	.33	.07	.00	.05
10 ft.	.13	.36	.22	.52	.12	.12	.07	.11	.07	.00	.04
11 ft.	.....	.45	.20	.36	.09	.13	.09	.....	.09	.00	.06
12 ft.	.....	.49	.16	.26	.07	.....	.11	.....	.09	.00	.09

It is a matter of much surprise that the heavy black clay or adobe soils of the state should, generally, have so little of humus in the upper three feet and especially in the surface soil. Only two of the eleven columns chosen as typical of the various black clay regions have as much as 2 per cent in the upper foot. The black adobe of the Sacramento and San Joaquin valleys have far less humus than was found in those of the Coast Range. It is also a surprising fact, well shown in these soils, that a black soil does not always owe its color to the humus that it contains, for all of those given in the table are very black and yet have but little humus; this is especially noticeable in those from

Tracy, Biggs, and south of Dixon, which have less than 1 per cent. A very striking example of this was found in a sample of adobe soil sent for examination some time ago from near the hills in the Santa Clara Valley, which although almost jet black had but a trace of humus.

It is further interesting to note that in the Berkeley and Walnut Creek columns there is more than 1 per cent of humus in each of the upper six and five feet below the surface respectively; in each of the upper three feet of the Santa Clara and San Ramon columns and in the upper two feet of the Willows column. In the Dixon, Tracy, and Biggs columns there is less than 1 per cent in the first foot.

In the fourth foot of the Santa Clara, seventh foot of the Berkeley, and third foot of the Yuba City there are very sharp drops in the percentages, and this is seen also in the lighter color of the respective columns at those depths. These indicate that the main root systems of the plants were confined to the upper part of these soils, while in other columns there was less of root mass and a greater downward development. In all except where ground water was found above the twelfth foot, the humus clearly could be found at greater depth, especially in the Berkeley column, which had 0.49 per cent in the twelfth foot.

The Santa Clara soil has in its first foot the highest percentage of humus of any soil of the state thus far examined, excepting the tule marshes; the same is true if we compare the average of the three upper feet and also that of the upper six feet, which are respectively 3.62 and 1.99 per cent. The general average of humus in the first foot of the eleven columns is 1.61, for the second 1.20, and for the third foot only 0.92 per cent.

Relation of Humus Percentage to Color and other Soil Characters

There are types of land having other than textural characteristics concerning whose relation to humus content some question may arise, and we have segregated some of the more important of these in the following table. They refer to the uplands and lowlands, the several color characters and to strong

alkali lands. We have omitted the tule marsh lands from the composite of lowlands, and the strong alkali lands and the desert lands from the composite of uplands.

TABLE 48.—AVERAGE HUMUS IN SOILS OF DIFFERENT CHARACTER AND COLOR

	Stream alluvial 5 columns	Non-alkali uplands 73 columns	Black lands 17 columns	Gray lands 16 columns	Red lands 10 columns	Alkali land 4 columns
1 ft.	1.41	1.18	1.19	.94	.64	.30
2 ft.	1.09	.91	.45	.69	.42	.26
3 ft.	.84	.65	.38	.57	.28	.23
4 ft.	.76	.37	.26	.47	.24	.18
5 ft.	.68	.42	.22	.44	.24	.16
6 ft.	.56	.36	.21	.40	.17	.08
7 ft.	.52	.35	.15	.37	.12	.08
8 ft.	.41	.27	.12	.30	.10	.06
9 ft.	.34	.25	.11	.31	.11	.04
10 ft.	.24	.24	.09	.28	.11	.04
11 ft.	.26	.23	.05	.25	.12	.04
12 ft.	.23	.23	.08	.22	.18	.03
COMBINATION OF UPPER AND LOWER PORTIONS						
Sum of per cents:						
Upper 3 feet	3.34	2.74	2.02	2.20	1.34	.78
Upper 6 feet	5.34	3.89	2.71	3.51	1.99	1.21
Lower 6 feet	2.00	1.57	.60	1.73	.74	.29
Total 12 feet	7.34	5.46	3.31	5.24	2.73	1.50
Average per ft.	.61	.45	.28	.44	.23	.12

The table shows the interesting and unexpected fact that in their general averages the alluvial lands that border the streams are but little richer in humus than the uplands, either in the surface foot or at the several levels to the twelfth foot. In the fourth foot the difference is 0.39 per cent, but in every other level it is less than that. In the upper three feet the difference is 0.60 per cent, in the upper six feet 1.45, and for the entire column it is only 1.88 per cent in favor of the alluvial lands. There are, of course, throughout the state instances of high percentages in single soils of both the alluvial and upland classes, and but for these the general averages would be much lower.

The close agreement in humus percentages of the uplands and alluvial lands, and the gradual and quite uniform diminution of the same downward plainly indicates that the source of the

humus in both classes is in the decay and humification of plants whose roots had penetrated to depths of many feet.

The small differences throughout the composite columns would also show that the alluvial lands and the deltas possess no material advantage, except perhaps in moisture conditions, over the higher lands which are of good depth and free from hardpan.

Relation of Humus to Soil Color.—It has already been pointed out that a black color does not necessarily mean the presence of a high percentage of humus, and this is again emphasized in the composite columns of many soils of three colors taken from the main agricultural regions of the state. In these the surface foot of the black has but little more humus than that of the gray soil (1.19 and 0.94 per cent respectively). But still more surprising is the fact that, although the upper three feet of the black lands are almost invariably very dark and even black, they contain less humus than the upper three feet of the gray sandy lands; and that throughout the entire composite columns the percentage of humus is greater in the gray than in the black soils with the exception of the first foot. There are, of course, black clay lands of Santa Clara, Arroyo Grande, and other localities which have high percentages, but these are offset by those with very small amounts.

The composite of eleven red lands embracing mesa and hill lands and the more level lands on the eastern side of the great valley contains less humus than either the black or the gray, except in the lower six feet.

The gray lands of the state seem therefore to have greatly the advantage over both the black and red classes in larger humus content and in its better distribution throughout the depth of twelve feet.

Humus in Strong Alkali Soils.—This column is a composite of four alkali soils from the San Joaquin Valley, including the Tulare Lake bed, and shows a deficiency in humus throughout. Alkali salts are usually held in the upper four feet of these valley soils and it is there where they would prevent the growth of vegetation with accompanying root systems whose decay would result in the production of humus. Hence we find but little more than mere traces of humus below the fifth foot.

HUMIC PHOSPHORIC ACID IN SOILS

While one of the chief values of humus lies in its content of nitrogen which is made available to plants by bacterial action, the mineral elements potash and phosphoric acid held by it are also of value to plants as fertilizers and are probably immediately available. The amount of phosphoric acid is especially quite large, as is shown by an analysis of the ash from humus of a productive prairie soil of Minnesota made by Professor Snyder.[11]

TABLE 49.—ANALYSIS OF THE ASH OF HUMUS

	Per cent
Ash (precipitated humus)	12.24
COMPOSITION OF THE ASH	
Silica	61.97
Potash	7.20
Soda	8.13
Lime	0.09
Magnesia	0.36
Ferric oxid	3.12
Alumina	3.48
Phosphoric acid	12.37
Sulfuric acid	0.98
Carbonic acid	1.64

Early in the investigation of the humus in these soil columns, we made examinations of the ash of the humus of a few of the soil columns to their full depth to ascertain how much, if any, phosphoric acid was present in an organic form combined with the humus below the upper few feet. The difficulty of securing a humus solution free from suspended clay makes the results given in the following table only approximately correct, though sufficiently so to be of special interest in showing that phosphoric acid does accompany the humus in all soils to depths of many feet, and being thus distributed downward throughout the soil mass is at the command of roots as they reach to water.

[11] Chemistry of Soils and Fertilizers.

TABLE 50.—PERCENTAGE OF HUMUS AND HUMIC PHOSPHORIC ACID IN SEVERAL OF THE SOIL COLUMNS

	Orchard Yuba City Clay loam		Orchard Chico Alluvial		Grain field Stockton Adobe clay		Grain field Modesto Sandy		Hop field Russian River Alluvial		Seed farm Santa Clara Adobe clay		Orchard Santa Paula Clay loam	
	Humus	Phosphoric acid	Humus	Phosphoric acid	Humus	Phosphoric acid	Humus	Phosphoric acid	Humus	Phosphoric acid	Humus	Phosphoric acid	Humus	Phosphoric acid
.ft....	1.27	.05	1.84	.05	1.16	.05	.37	.01	1.30	.07	4.48	.07	1.23	.07
.ft....	1.08	.04	1.18	.04	.76	.03	.27	.01	1.24	.09	3.66	.04	1.36	.07
ft.	.45	.02	1.16	.03	.50	.02	.19	.01	1.20	.08	2.80	.02	.52	.04
ft....	.39	.02	.88	.02	.22	.02	.18	.02	1.18	.06	.61	.06	.57	.04
ft....	.67	.02	.58	.01	.22	.04	.17	.01	.75	.03	.27	.05	.54	.04
ft....	.48	.03	.42	.02	.18	.03	.16	.01	.61	.02	.20	.05	.48	.02
ft....	.22	.03	.40	.01	.11	.02	.17	.01	.48	.03	.62	.09	.54	.04
ft....	.16	.02	.36	.01	.09	.01	.....	....	.78	.07	.23	.05	.45	.05
ft....	.12	.02	.38	.02	.08	.02	.....	....	.64	.07	.30	.08	.36	.05
ft....	.11	.01	.46	.02	.07	.01	.....	....	.52	.08	.....	....	.51	.04
ft....	.12	.01	.32	.02	.09	.02	.....	....	.54	.04	.....	....	.60	.03
ft....	.11	.01	.52	.02	.11	.02	.....	....	.22	.04	.....	....	.52	.03
ul available phosphoric acid in soil:														
ft.		.18		.09		.06		.11		.18		.12		.12
ft.		.11		.10		.11		.11		.23		.10		.19
ft.		.09		.13		.23		.13		.26		.12		.22

It will be seen from this table that the highest amounts of phosphoric acid in organic combinations occur in the upper two feet of each column with the exception of the Russian River and the Santa Clara, each of which have high percentages in their lowest depths, although the amount of humus is much lower than in the upper part.

The general average is 0.05 per cent for each of the two upper feet of the seven columns, 0.03 per cent for each of the succeeding eight feet, and 0.02 per cent for each of the two lowest feet of the five columns whose depth reaches twelve feet respectively.

If we estimate the percentages into pounds per acre, we find that the amount of this humic phosphoric acid for the column is approximately as follows:

	Surface foot	Upper 3 feet	Entire column
Yuba City, Sutter County	2,000 lbs.	4,800 lbs.	11,200 lbs.
Chico, Butte County	2,000 lbs.	4,800 lbs.	10,800 lbs.
Stockton, San Joaquin County	2,000 lbs.	3,600 lbs.	11,600 lbs.
Russian River, Sonoma County	2,800 lbs.	9,600 lbs.	26,400 lbs.
Santa Paula, Ventnra County	2,800 lbs.	7,200 lbs.	15,600 lbs.
Santa Clara, Santa Clara County	2,800 lbs.	4,800 lbs.	20,400 lbs.
Modesto, Stanislaus County	400 lbs.	1,200 lbs.	3,200 lbs.

Even in the upper foot of each of the above there is from 2000 to 2800 pounds, with the exception of that of Modesto, which has only 400 pounds of phosphoric acid per acre.

When we consider the fact that 0.05 per cent or 2000 pounds per acre of available phosphoric acid is regarded as a sufficient amount for soil fertility for present needs, we can readily see that these particular soils, except that from Modesto, are abundantly supplied with phosphoric acid for many years.

Analyses of the first, sixth, and twelfth foot respectively of the columns also show the presence of large percentages of available potash.

Comparison of Arid and Humid Soils

A comparison between the soils of the arid and humid regions brings out the very great advantage possessed by the former and especially by those of California over the humid, as shown in the first part of this bulletin. But it is especially marked in the amount and distribution of humus in the soils of the respective region.[12] The general average in 280 soils of the humid portion of the United States is 2.63 per cent, and if we add to this the 5.26 per cent in eleven tropical soils of Hawaii the average is brought to 2.73 per cent, or approximately 109,200 pounds per acre in a depth of twelve inches.

The average of the 331 California soils and forty-four from Idaho, Arizona, and Oregon is 1.28 per cent for the surface foot, or less than one-half that of the humid region. For the first

[12] It has been a rather difficult matter to secure data on humus in the soils east of the Mississippi River for the reason that in their analysis some of the chemists have failed to separate it from the percentage of aggregate "organic matter."

foot of the 109 soil columns including the marsh lands the average is 1.35 per cent.

But the depth of soil in which most of the plant roots are held in the arid region, and in which the humus color is most pronounced is *three feet*, and taking this as the true soil of California we find that there is a sum of 3.17 per cent, or an average of 1.06 for each foot; this is equivalent to about 127,000 pounds per acre. To this should be added the percentages of humus found at lower levels of the soil, as shown in the averages of the 109 columns given in the accompanying table, which would bring the total humus to 233,000 pounds in twelve feet.

TABLE 51.—AVERAGE OF HUMUS IN ARID AND HUMID SOILS

	ARID SOILS		HUMID SOILS
Ft.	109 California soil columns Per cent	342 soils in United States Per cent	291 soils in United States Per cent
1.	1.35	1.28	Soil 2.73
2. Soil	1.04	?	?
3.	.78		00
4. Subsoil	.62		00
5.	.45		00
6.	.36		00
7.	.30		
8.	.26		
9.	.21		
10.	.18		
11.	.14		
12	.14		
Sum of per cents in 12 ft.	5.83		
Sum of per cents in 3 ft.	3.17		
Nitrogen in humus, 3 ft.....	5.60		
Nitrogen in soil, 3 ft.....	.05		

The amount of humus then in the average of California soils (three feet deep) is greater than in those of the humid region; and for the depth of twelve feet it is more than twice as great.

The determinations of humus-nitrogen in the soils of the humid region have been so few and miscellaneous that it is not advisable to deduce from them an average to represent the whole region.

Arid California with her deep soils of well diffused humus and richness in plant food thus possesses very great advantages over the more humid east where a depth of six to nine inches is very generally accepted as that of a true upland surface soil, containing practically all of the humus and marked by a very sharp change of the black humus color to the gray and yellow subsoil with its inappreciable amount of humus.[13] In the sediment lands of the streams and some of the black prairies the humus is of course found at a greater depth.

CONCLUSIONS

1. The depth of the soils of California is indefinite because of the presence of humus and available plant food to and beyond twelve feet below the surface. It may be several times twelve feet, being limited only by ground water, country rock or heavy beds of gravel; layers of hardpan at a depth of several feet would limit the depth for small cultures, but may be broken up with dynamite and the depth greatly increased for the extension of tree roots. There are in reality none of those difficultly permeable clay subsoils that characterize humid soils and limit their depth to but a few feet. The sharply defined change of the black humus color to gray at six or nine inches that marks the depth of humid soils is present in some of the heavy clay soils in California at the depth of three feet, but for the most part the change in tint is very gradual downward through many feet. The upper three feet may, however, properly be called the soil, for in that depth the greater part of the feeding roots of plants are found.

2. The soils of California are richer in humus than has generally been supposed; in their depth of three feet (the soil proper) they contain more than in the humid soils, and in the entire columns of twelve feet or more they have double that of the humid soils.

[13] See Hilgard's Soils, p. 164, and Agricultural Science, 1892, p. 263; King's The Soil, p. 29; Hall's Soils, p. 45; Minn. Agr. Expt. Sta. Bull. 30, 41, and 65 contain analyses of 121 subsoils, in only sixteen of which is humus reported though found in all of the corresponding surface soils which were taken to depths of nine inches. (Bull. 30, p. 164.)

3. The humus in California soils is usually distributed through depths of twelve or more feet, the highest percentage being in the upper three feet and diminishing downward as shown in each of the 109 soil columns taken from the seven agricultural regions; as much as 41 per cent was found in the fifteenth foot of the Ft. Romie column. and 0.74 per cent in the thirteenth foot of that of Davis and Hayward; water was reached in each case.

4. The surface soils of California have an average of 1.28 per cent of humus as shown in the analysis of several hundred samples taken from the many agricultural regions of the state. This is not sufficient to maintain good tilth in the soil; but as supplemented by that of many feet below often affords a fair supply of nitrogen. The upper three feet of soil proper has an average of 1.06 per cent per foot, or a sum of 3.17 per cent.

5. The tule swamps have the highest percentage of humus because of the mass of decaying roots and other vegetable matter, while the desert plains have the least.

6. Humification is retarded in close compact adobe clays and the amount of humus is less than in lighter loam and sandy soils.

7. The valleys of the Coast Range in the western part of the state have higher percentages of humus in their soils than have any of the other agricultural regions of California, probably because of the greater humidity of the climate of that region and a denser vegetation.

8. The humus of the soils of this state is very generally derived from plant roots instead of from accumulations of vegetable material at various depths as the soil was being built up, thus showing that the native vegetation has for ages been deep-rooted.

9. The black color of a soil is not always due to a high humus content; many black soils have a smaller percentage of humus than soils of a gray color. In one instance a very black clay soil from the Santa Clara Valley contained no humus, its color being due to the presence of a black rock powder.

10. Humus contains nitrogen in combination, the amount depending largely on the source of the humus. The average percentage in the humus of the first foot of the soil columns is

5.92 per cent; that of each of the upper three feet is 5.60, and a little less for the entire twelve feet. It varies from 1 to 20 per cent in individual soil layers.

11. The organic nitrogen in the soil derived from the humus and dependent on the amount of the latter, varies from almost nothing in the lower depths of the soil to as much as 0.13 per cent in the upper three feet. The average of the first foot of the soil columns is 0.07 per cent; for each of the three upper feet, the range of most annual plant roots, it is 0.05 per cent. The investigations of Professor Lipman of this station show that nitrifying bacteria are present and active in California soils to depths of six feet and ammonifying bacteria are present through a depth of twelve feet, thus making available to plants the nitrogen content of the humus to these depths.

12. Humus contains soluble mineral plant food in combination, the phosphoric acid being present in the humus of California soils to the extent of from 0.01 per cent to 0.08 per cent throughout the entire depth to which humus reaches, though usually greatest in the upper few feet.

13. Humus is sometimes less in the first foot than in the second because it is gradually destroyed by cultivation and summer fallowing of the soil, but may be replaced and increased by proper methods of green-manuring, or the turning-under and humification of legumes.

14. Arid soils have an immense advantage over those of the humid region of the United States because of this distribution of humus and its nitrogen, as well as of mineral plant food, through a depth of many feet, as it gives a greater depth of soil and induces a deeper root penetration for plants and trees into a greater feeding area and where there is more moisture. The wonderful endurance of drought on the part of California soils is due to this.

15. The practical value and hence the commercial valuation of land in California cannot be based alone upon the nature of the surface soil and subsoil as in the humid region, but chiefly upon its texture and depth, and upon the freedom with which plant roots are able to penetrate to many feet and secure moisture and the abundant food supply that exists at those depths in all of California soils.